



DIVISION 1
GENERAL AND SITE FACILITIES

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1.0 Introduction

All divisions of this specification shall apply to road, bridge and other supporting works required to be executed under GoB and other contracts or otherwise as directed by the Engineers. In every cases, the work shall be carried out to satisfy the Engineer and shall confirm to the location as specified in the contract and dimensions, grades, cross sections as specified in the approved drawings or otherwise directed by the Engineer. All the ongoing and completed works under GoB contracts shall ensure the RHD Quality Assurance Plan, 2005 or the updated approved version, whichever is available. The works under foreign aided project shall conform to the quality assurance plan approved by respective Engineer. In all GoB or foreign aided projects, the contractor shall prepare the quality assurance plan as recommended above to submit to the Engineer prior to the commencement of work to cover all stages of works such as setting out, selection or approval of construction material, method, equipment or plant, quality assurance tests (methods as described in RHD standard test procedures or this specification or as approved by the Engineer).

1.1 Scope of the Works

The work to be conducted under the contract contains various items described in the contract documents as well as in the Bill of Quantities of that documents.

1.1.1 Conformity with Drawings

All works completed and all materials furnished shall conform the lines, grades, typical cross sections, layout, dimensions, material and other requirements along with tolerances (if mentioned any) shown in the drawings. The drawings in the tender documents shall be used as reference and contractor shall ensure that the price quoted by him in the Bill of Quantities cover the complexity of the nature of the works during the full process of construction. The drawing shall include the location drawings for each contract with start and end point of the work under contract documents. In the absence of topographical mapping and plan layouts, every contract must include the location and extent of the major work items showing the start and end chainages (in bar chart form). Where surface water drainage is required and is to be included in a works contract, a longitudinal plan showing the gradients and outfalls shall be included within the contract documents. This can be in diagrammatic form but must show the relevant information required by the Contractor for the drainage to be constructed by him.

The contractor shall, based on proper surveys and site investigation, submit the working drawings (hard and soft copy) to the Engineer of each activity prior to atleast 30 days before the commencement of that activity. If any modification is proposed in the working drawings, it shall be examined by the Engineer to make necessary approval steps (if needed) as mentioned within the contract documents or Engineers authority as stipulated in other approved documents of RHD. Examination or approval of these drawings by Engineer shall not relieve the contractor of his liabilities under the contract.

1.1.2 Bills of Quantities

For every item of work within a contract where an estimate has to be made of the quantities involved and supported by appropriate field measurements, calculations shall be made that are checked and approved by the Engineer and filed in the document control system. All BQ items must correspond to the relevant pay items in the RHD Specification or the Particular Specification for the Contract.

1.1.3 General and Particular Specification

The approved general specification must form the basis of all RHD road contracts supplemented where necessary by a Particular Specification for an individual contract. Accordingly, it is essential that in the preparation of Tender Documents, latest and current version of the Standard Tender Documents shall be used for the type of contract to be undertaken. These Standard Tender Documents and the contract specific details are to be checked and approved by the Engineer prior to the floating of tenders.

1.1.4 Site Information and Setting Out

The site information included in the Tender documents is given to the contractor in good faith for guidance only, whereas the contractor shall be responsible to satisfy himself regarding the site conditions before commencement of works. The contractor shall establish working bench mark tied with Reference bench mark (as indicated in the tender documents) after taking possession of the site. The no of working bench marks shall be four per km and near all drainage structure, overpass or underpass and it shall be checked and approved by the Engineer.

The lines, grading, level of formation, side slopes, drainage works, carriage way with right off area shall be carefully set out with correct gradients and cross section whenever necessary by the contractor and regularly checked for any adjustments.

1.1.3 Quality Assurance Plan

All GoB works will be covered by RHD Quality Assurance Plan whereas foreign funded projects can have their own plan approved by concerned Engineer. The Quality Assurance Plan will cover all the process starting from document preparation prior to construction work and during the construction work process. The contractor shall conform to all actions are taken in terms of planning, management and execution of the work in accordance with that quality assurance plan during the construction period. The contractor will submit a quality assurance plan to the Engineer covering all the aspects of setting out, selection of material at source, plant and equipment with capacity as indicated in the tender documents, staff personnel, document and data control, construction program, arrangement for traffic maintenance during construction, construction methodology, quality control tests, site laboratory and other facilities in accordance with RHD Quality Assurance Plan, 2005, or as instructed and approved by the Engineer.

1.2 Maintenance and Protection of Traffic

1.2.1 General

From the date of Commencement of the works as provided in the contract, the Contractor shall be responsible for maintaining an uninterrupted and safe passage for vehicles and pedestrians along the project road, detours, diversions and temporary structures. During construction due attention shall be paid by the Contractor to the maintenance and riding comfort of all such roads, detours, diversions and temporary structures therein at all times during day or night. In view of that, the contractor shall provide, erect, operate and maintain all necessary signs, signals, lights, markings, barricades, diversions, detours and temporary structures with utmost care and diligence.

This section of the specification includes provision for pedestrian and vehicular traffic on:

- Sections of existing road where work has not commenced or is not required;
- Sections of existing road where work is in progress;
- Detours required in accordance with the drawings or as ordered by the Engineer or as otherwise required by the Contractor's work method.

The types of maintenance situations described below include:

- (i) Construction and maintenance of detours away from existing road that are required because the full width of the existing road is under construction or where works on cross drainage structures requires the provision of a detour;
- (ii) Construction and maintenance of diversions along an existing embankment where road construction is underway at half width beyond the proposed centerline;
- (iii) Maintenance of existing road where works have not commenced or is not required;
- (iv) Maintenance of completed half width of the project road and shoulder opened to traffic;

The Contractor's responsibility shall include the necessary rectification of any deterioration or damage to the road, intersections or driveways and drainage structures due to passage of traffic or rains or flood. The specific location of any detour or diversion shall depend upon the Contractor's method of working and the Contractor shall be deemed to have covered all the cost of the same while quoting his price.

The Contractor shall so conduct his operations as to offer the least possible obstruction and inconvenience to the traffic movement. He shall have under construction no greater length or amount of work than he can properly handle at a time without affecting the free flow of traffic.

Unless stated otherwise in this specification, all traffic shall be permitted to pass through the sections of the works which have been already completed and opened to traffic in accordance with the contract.

Areas of existing public roadway, traffic diversions or detours shall not be obstructed or used in any way by the Contractor for the dumping or stockpiling of materials or parking of Contractor's equipment.

At least 15 days before commencing work on any section of the project works, the Contractor shall submit to the Engineer proposals for the maintenance of traffic including the Working Drawings for traffic control arrangements, road signs, and any temporary road works including detailed typical cross sections of the proposed detours/diversions indicating clearly the type of diversion, construction materials and thickness of the pavement structure and surfacing not inferior to the specifications stated hereinafter and a program showing the time over which the detour/diversion is required to be operational to provide a smooth and safe passage through the construction area.

The Engineer may require changes to such proposals of temporary works prior to approving the proposal and program. The standard of road surfacing required may depend on the duration that the detour/diversion is required to be operational. Approval to the Contractor's proposal shall not take away the Contractor's obligation to provide for an uninterrupted passage of vehicles and pedestrians at all times. Where necessary the Contractor shall strengthen by the addition of extra pavement layers or by additional compaction or any other means any detours or diversions that may be found inadequate for traffic with no extra cost to the contract.

1.2.2 Access to Adjacent Property and Intersecting Roads

Construction operations shall be conducted in such a manner as to cause as less inconvenience as possible to the abutting property owners. At all times and at no extra cost to the contract, access to private entrances and buildings along the line of the work shall be maintained and temporary approaches to any intersecting roadways shall be provided and kept in safe and trafficable condition. Existing approaches from intersecting roads or private entrances, which may temporarily be damaged or rendered ineffective by the works, shall be repaired or reconstructed as the case may be and maintained according to the approval of the Engineer until the permanent access required in the works is completed.

1.2.3 Width of Carriageway for Detours and Diversions

Where construction or maintenance operations interfere with the traffic, the Contractor shall keep open not less than a 6.0 m wide (two-way) carriageway unless otherwise specified or approved by the Engineer. Where-ever practicable, the Contractor shall widen the existing road embankment so that the required carriageway width of 6.0 m can be provided while construction works on the other half of the road embankment is progressing.

Where it is not practicable to provide for 6.0 m width as described above, for example, the approach to an existing culvert where work has been taken up over half of its width, not less

than 3.0-meter clear carriageway width shall be made available for one-way traffic. The length over which the road may be closed for half width and one-way traffic provided shall not exceed 400 meter and the passage of traffic shall be controlled in one way operation by the Contractor either manually or by using automatic signals, which shall be supported at all time by man in case of failures.

1.2.4 Assistance to Public

No diversion shall be opened to traffic without ensuring a prompt availability at all time of men and equipment to remove any stranded vehicle from the diversion/detour sections.

The Contractor at all times shall be prepared to render immediate assistance to pedestrians or to the drivers or passengers of any vehicles who may be delayed, obstructed or stranded while on the sections of the works under his control.

1.2.5 Night, Weekend and Holiday Traffic

At night and during weekends and public holidays, where construction or maintenance operations interfere with traffic, provision shall be made for vehicles and pedestrians to have an un-restricted and safe use of a 6.0m wide carriageway. Should an emergency occur so that a 6.0m wide carriageway is not available, the contractor must employ all safety measures possible as directed by the Engineer. The cost of such emergency measures will not result in extra payment, and are deemed to have been included in the contractor's quoted price.

1.2.6 Barriers

The Contractor shall provide and erect all lights, signs, equipment and barriers required to ensure complete control of traffic, the safety of public and workmen employed in the works. Barriers shall be used for closing of lanes or roads, the protection of workmen and regulation of vehicular traffic. The main requirements are:

- a) Barriers shall be constructed of steel tubes and concrete or of other material (New Jersey Barriers either of concrete or plastic one filled with water or sand can be used) subject to approval of the Engineer. The barriers shall be conforming to the design, dimensions and color of the barrier shown in the approved Working Drawings submitted by the Contractor or such other design as may be approved by the Engineer.
- b) Trestles supporting barriers shall be neatly and stoutly constructed of sawn timber, concrete or other material subject to the approval of the Engineer. Trestles shall serve as firm supports for the barriers but the bases shall not protrude beyond the ends of the boards.
- c) Provision shall be made for the attachment of warning lamps to the trestles or barriers where the barrier is to be left in position overnight.
- d) Where part-width of the road is to be closed to traffic and the closed strip is not required for actual working, additional barriers shall be erected across the closed portion of the road. The Contractor shall take positive measures, including the use of centerline lane barriers and manned gate barriers, to prevent traffic from forming double line queues at stop signs.

- e) Where work is actually in progress on part of the road, a line of barriers shall be erected between the work area and that portion of the carriageway which is available for traffic.
- f) Advance warnings shall be erected and barricades shall be provided at the entry/departure point of the detour in such a way as to completely obstruct and prevent traffic from entering incomplete sections of the works or bridges/culverts under dismantling and reconstruction. Barriers or barricades shall be constructed as required for the situation to the satisfaction of the Engineer.

1.2.7 Plant and Equipment

During the day, if working in a position adjacent to traffic, plant items having projections beyond the normal width of the item (e.g. a grader blade) shall have a red cotton flag attached to the outer end of the projection for traffic safety.

At night where traffic is permitted to use the whole or portion of the existing road, all plant items and similar obstructions shall be removed from the normal path of vehicles to provide a lateral clearance of at least 3 m if practicable and with an absolute minimum of 1.5 m.

Plant and equipment, within 150 mm of the edge of the pavement or detour or side-track, shall be lit at night by not less than two amber lamps suspended vertically from the point of the obstruction nearest to a traffic lane and one amber lamp at each end of the obstruction on the side furthest away from the traffic lane.

1.2.8 Maintenance of Traffic Control Devices

All Traffic control devices shall be maintained in good working condition and in the correct position at day and night. They shall be neat and clean; all traffic signs shall be clear and legible at all time. Sidetracks shall be maintained in good order at all time. Except otherwise permitted by the Engineer, all traffic-controlled sections of the road shall be manned at all time. Outside normal working hours, the Contractor shall maintain a duty officer and a labor gang with transport on call at all time to take care of urgent repairs or alterations to traffic control systems and/or equipment whenever required. He shall keep the Engineer's Representative and the nearby Police Station informed of the Duty Officer so that they could communicate in case of any emergency.

1.2.9 Effective Traffic Control with Road Maintenance

The maintenance of the existing road, detours or diversion with effective control of traffic shall be considered a prime responsibility of the Contractor. If in the opinion of the Engineer, a situation has arisen where lack of maintenance is creating hindrance to free flow of traffic or causing distress to travelling public, the Engineer shall be free to engage, after giving 3 day's written notice to the Contractor, any agency or agencies to undertake the work causing such hindrances.

All costs associated with taking such action will be recovered from the amount that is or that may become due to the Contractor. It shall be explicitly understood that recoverable amounts may not be limited to the rates quoted by the Contractor or any pay item against such

maintenance works. The decision of the Engineer regarding the amount to be deducted from the Contractor shall be final and binding upon the Contractor.

The Contractor shall provide only such labor on traffic control as have been properly trained or have previous experience. They shall be persons of proven comprehension and competence in the courteous and efficient control of the vehicular traffic.

Persons controlling traffic shall wear distinctive brightly colored (yellow, orange or similar) uniforms and shall be provided with waterproof clothing in easily visible colors and weather shelters when required.

1.2.10 Specifications and Measurement for Construction & Maintenance of Detours and Diversion for Typical Situations and Maintenance of Existing Road

1.2.10.a Detours Away from Existing Road Embankment and Diversions for Cross-Drainage Structures.

(i) Specification

A detour shall be constructed away from the existing road where the full width of the road is under construction or where cross drainage structural works requires its provision. The provisions under this clause shall also apply for diversions constructed for structures under reconstruction or rehabilitation works. No detours and/or diversion will be approved in cases where the new carriageway is to be constructed on a different alignment to the existing carriageway.

Detour shall be so constructed that its pavement surface always remains at least 0.5m above the expected water level during its whole service period. The surface shall be shaped, adequately compacted, leveled, and graded to provide a trafficable pavement to the satisfaction of the Engineer and shall contain temporary cross drainage pipes/culverts, wherever is required, to ensure uninterrupted passage to traffic during the execution of the works. Connection to existing roads and tracks shall be graded to provide smooth junctions. The pavement shall be properly maintained in a smooth, hard and serviceable condition at all times. The detour construction shall be of a minimum carriageway width of 6.0 m plus 1.0 m earth shoulder on each side.

The pavement structure for the detours shall be provided in view of the length of time and season of the year it is proposed to carry the traffic load and subject to the approval of the Engineer. When a detour is required to be operational for more than 3 months, the following specification shall be considered.

- (a) a well compacted soil sub-grade covered with a minimum 300 mm thick improved sub-grade of soil sand mix compacted to 95% MDD (AASHTO: T-180) overlaid with 200 mm Sub Base, 100 mm Type 1 Aggregate Base and 50 mm Bituminous Base Course, to be decided by the Engineer depending on site condition.

If the diversion required to serve the traffic for period of 3 month, Herring Bone Bond (HBB) over Brick Flat Soling (BFS) constructed with approved picked Jhama bricks or

equivalent materials with their joints filled with approved sand.

All costs shall have been included in the pay items for construction of diversions/detours. No traffic will be released over a diversion until inspected and approved by the Engineer's Representative. The Contractor shall maintain the detour so constructed to the satisfaction of the Engineer. Any potholes or undulations may appear in detour/diversions constructed with granular layer shall be repaired with granular materials and bituminous treatment as necessary.

The detours and diversions for drainage structures shall be maintained with utmost care and diligence for the full-service period and any damage and defect shall be repaired forthwith to the satisfaction of the Engineer.

Temporary bridge detours shall be constructed on permanent bridge construction site. These temporary bridges will be capable of safely carrying all road traffic and may be of one lane width. The contractor must submit design calculations and plans of all temporary bridge proposals for the Engineer's approval before the construction commences. Also, the contractor must obtain the Engineer's approval of the temporary bridge constructed before traffic is allowed to use it. The same conditions shall apply for road detours regarding attendance on traffic and maintenance of the temporary bridge.

The Contractor will be permitted to use any land within the right of way for the purpose of constructing detours/diversion roads. However, where the land available is unsuitable or insufficient in any way, the Contractor shall make all arrangements and pay all costs incurred in obtaining the temporary use of any land outside the right of way. Such costs shall be deemed to have been included in the rates for the pay items for all works for detours including their removal after their period of service.

As soon as possible after the completion of any part or whole of the works and prior to the issue of a Taking over Certificate as per Clause 48 of General Conditions of Contract (GCC), all detours, diversions or passing places that have been constructed shall be restored to their original conditions at no additional costs.

ii. Measurement

Construction and maintenance of detours away from an existing road embankment shall be measured in km. The construction of diversions and detours for cross-drainage structures shall be measured in meter when they have been constructed ready to accept traffic and to the engineer's satisfaction. No separate measurement will be made for temporary culverts in diversions and detours as they shall be deemed to be included in the measured km or meter amount. Temporary bridges constructed as part of detours on bridge sites shall be measured in meter length as approved for construction by the Engineer. The measurement for maintenance of diversions and detours including temporary bridges of any cross-drainage structure described above shall be measured in "m-month" when completed to the satisfaction of the Engineer and shall be considered

for payment up to the period the traffic is allowed. Such period shall not be considered more than that allowed for the intended life of the diversion/detour as per the approved work program.

1.2.10.b Diversions in the existing embankment when road construction is taken up on the half width beyond proposed centreline.

(i) Specification

Except where the Contractor is authorized to construct a detour, the construction work on an existing carriageway shall generally be taken up in part widths. Roadway excavation and/or the earthwork in embankment fill required for the construction of the diversion shall be taken up in such a manner so as to provide a reasonably smooth and even profile for the satisfactory use of traffic.

The total width of carriageway for the diversion including the available part width of the existing embankment or carriageway shall not be less than 6.0m with 0.5m shoulder at the inner side and 1.0m wide earth shoulder on outer side. However, it shall be noted that part width of the existing carriageway may or may not be available for the diversion depending on the position of the proposed centerline. If additional embankment fill is required specifically for the diversion (temporary works), the placement of temporary fill and its removal, after its service period shall be deemed to have been included in the related pay item for the diversion works. The cost of embankment construction that forms part of the permanent Works shall be included under pay item for Earthworks as applicable. The earthwork in embankment stated above may also be replaced with earthwork in cutting depending upon the site conditions.

If it becomes impractical to provide the desired width, a narrower width may be considered but only with the explicit prior approval of the Engineer.

The composition of the new pavement structure to be constructed alongside the existing pavement, as part of total 6.0m wide carriageway for the diversion (temporary works) shall be considered commensurate with the length of time and season of the year it is proposed to carry the traffic subject to approval by the Engineer. For a diversion required to serve the traffic for periods in excess of 3 months, the following specification for the pavement shall be considered:

- (a) a well compacted soil sub-grade covered with a minimum 300 mm thick improved sub-grade of soil sand mix compacted to 95% MDD (AASHTO: T-180) overlaid with 200 mm Sub Base, 100 mm Type 1 Aggregate Base and 50 mm Bituminous Base Course, to be decided by the Engineer depending on site condition.

When part of diversion is constructed with granular layers, the finished surface shall be primed with cutback bitumen and shall be provided with a premixed bituminous seal coat to keep the road trafficable. The Seal Coat shall have 0.015 cum of pea-gravels blended with 0.01 cum of sand (FM 0.8) with 80 kg of bitumen per cum of pea-gravels on 1.0 Sqm

road surface and rolled by 8/10T Steel Roller. No traffic will be released over a diversion until inspected and approved by the Engineer.

The Contractor shall maintain the diversion so constructed for its service period to the satisfaction of the Engineer. Potholes and undulations in any part of the diversion constructed with granular layer shall be repaired with granular materials and bituminous treatment as necessary. If any width of the existing pavement forming a part of the temporary diversion, it shall be maintained to the level and specification stated above.

The diversion shall be maintained with utmost care and diligence for its full-service period and any damage and defect shall be repaired forthwith to the satisfaction of the Engineer.

(ii) Measurement

The measurement for construction of diversion & its maintenance for passing traffic along a part of the existing carriageway during construction period shall be made in km-month with no separate measurement to be made for culverts should they be required.

1.2.10.c Maintenance of existing road where works have not commenced or is not required

(i) Specification

Within the limits of the project road, the Contractor shall carry out routine maintenance work on all sections of existing carriageway and shoulders that are being used by traffic in a safe and trafficable condition. Potholes, broken edge, pavement defects and washouts shall be promptly repaired to an acceptable condition all according to the specifications stated hereinafter and to the satisfaction of the Engineer.

Material falling out on existing carriageway as a result of carting or clearing operations and other obstructions to traffic including dead animals and crash debris shall be removed immediately by the Contractor.

Unless otherwise approved by the Engineer, the Contractor shall not by his operations obstruct any side road or branch track, or break down any fence or obstruct any drain or water course, nevertheless if such blockages occur, he shall at once remove and repair the blockages. Should the Contractor neglect to remove such obstructions or repair damages, the Engineer may take action to have any necessary work carried out and the cost thereof will be deducted from any amount that may be due or become due to the Contractor.

The Contractor shall take full care that his construction equipment's and vehicles do not cause any damage to the bridge on the works or to the adjacent sections of roads. Bridges required to carry loads in excess of their apparent capacity shall be propped or be deck plated where punch through may occur. The Contractor shall be responsible for the replacement or repair, at his own cost, of any damage to the bridge by his equipment or activities, and will have no claim on the Employer for any time loss or disruption of

work due to collapse of any bridge. In the event of a bridge failure as mentioned, which severs traffic passage in the contract area, the Contractor will provide a temporary by-pass without delay and in no case in not more than 24 hours' time following the breach of such passage.

The road shall be maintained with utmost care and diligence for its full-service period and any damage and defect shall be repaired forthwith to the satisfaction of the Engineer.

(ii) Measurement

The measurement for the maintenance for passing traffic along an existing road where works has not commenced or where no work is required shall be measured on a monthly basis provided the Engineer is satisfied that the Contractor has met his obligation under this clause.

1.2.10.d Maintenance of completed half width of road and shoulder opened to traffic:

(i) Specification

The half-constructed part of the pavement along with the hard shoulder and the additional diversion part as per the approved Working Drawings shall be considered together to provide a minimum carriageway width of 6.0m for the temporary passage of traffic.

The hard shoulder part including additional width shall be scarified and recompacted adding new materials as necessary to the satisfaction of the Engineer. The hard shoulder and the diversion shoulder part shall be duly repaired, compacted and mended for any loss of thickness and potholes, if any, to prepare them to be used by the traffic. After the other half of the roadway has been constructed, the full width of road will be opened to traffic.

Any damage to the constructed bituminous pavement in part widths that is opened to traffic shall be made good to the satisfaction of the Engineer and the cost for such repairs shall be deemed to have been covered under the Contractor's defects liability of completed works and making good for any such damage shall reflect no additional cost to the contract.

Payment for construction of hard shoulder and additional diversion width with sub-base materials as shown in the typical cross-section in the Contract Drawing or as directed by the Engineer shall be made under relevant payment clauses and payment for repair and maintenance work for the period the shoulder being used by the traffic as per the approved time cycle shall be covered under general obligation of the Contractor.

(ii) Measurement

No separate measurement will be made for this item. All costs for discharging the obligations under provision for maintenance and provisions for traffic shall be deemed to have been included in the rates for the permanent works items associated with this activity.

1.2.10.e Maintenance of Traffic on exposed granular layer in carriageway under construction:

No traffic shall be allowed on exposed granular layers in carriageway under construction.

1.2.11 Dust and Mud or Extraneous Materials on Roads

(i) Specification

The Contractor shall take all reasonable measures to minimize dust nuisance during construction of the works. All existing roads being used by the Contractor's or Sub-Contractor's or Supplier's vehicle, plant and equipment and similarly the new roads which are part of the permanent works being used by the traffic, shall be kept clean and clear of all dust/mud/debris dropped from the vehicles/plant/equipment. Likewise, all dust/mud/extraneous materials from the works spreading on the road surface shall be cleared immediately by the Contractor.

The materials shall be removed immediately by manual sweeping, if so, directed by the Engineer, or by mechanical sweeping and clearing equipment and all dust, mud and debris shall be completely removed from the road surface. The road surface and diversion being used by traffic shall be watered daily during dry season to prevent dust nuisance and the Contractor shall keep provision for water tanker (bowzers) of at least one tanker for each 10 km project length or part thereof wholly devoted to this purpose.

(ii) Measurement

All these activities shall be deemed to be the General Obligations of the Contractor and deemed to have included in his rates and no separate payment shall be made.

1.2.12 Measurement and Payment

The work shall be paid at the contract unit rate for the item listed below & shown in the BOQ. Payment shall be for full compensation for performing work for construction of diversion and its maintenance works including all labor, carriage, material, tools, equipment, cutting pavement all complete as necessary for the work, taxes, profit and overhead.

Pay Items shall be:

BOQ ITEM	DESCRIPTION	UNIT

1/2/1	Detours 6m wide carriageway. The construction and maintenance and removal of approved detour/diversion, away from the existing road embankment, on original ground with temporary pavement on earthwork and cross drainage, except in diversions for construction of structures.	Lane/Km
1/2/2	The construction and removal of diversion/detours at culverts and bridge sites subject to the Engineer's prior approval Temporary road diversion 6m wide carriageway Temporary bridges minimum 3m wide	mm
1/2/3	Construction and maintenance of the diversion road for passing traffic along a part of existing carriageway during construction period including dressing and leveling existing road flanks, providing temporary signboard, barrier etc. all as per direction of Engineer.	Km-month
1/2/4	Maintenance of existing road where Works have not commenced or is not required	Month
1/2/5	Maintenance of diversion both pavement and temporary bridges constructed as per Clause 1.5.10.1 so as to maintain traffic for the period of construction of both culverts and bridges.	M-month

1.3 Field Office for The Engineer and Other Facilities to Be Provided by The Contractor

1.3.1 Field Office for the Engineer and his Staff

In addition to the office space required for his own use, the Contractor shall provide and maintain a furnished field office for the use of the Engineer and his staff. Requirements for the office construction, including overall size, number and size of individual rooms, and furniture are stated in Particular Specifications Clause 1.2.1 in Section 7 of Volume 1-The Tender.

The field office shall be maintained in a secure and watertight condition by the Contractor until the completion of the works or as otherwise instructed by the Engineer and shall be provided with electricity, potable running water and sewerage connections. All doors shall be fitted with approved locks, and windows shall be provided with mosquito screens and blinds and shall have interior locking-devices.

Before construction, the Contractor shall submit for the approval of the Engineer, plans and drawings showing proposed details and location for the field office, including foundations, access roads, shades, layout of electrical and water supplies and hard standings thereto. The Engineer may require revision of the plans prior to giving approval for construction. The Contractor shall also submit details of proposed furniture and fittings to the Engineer for approval.

The office, complete with furnishings, fittings, access roads and hard standings shall be ready for occupation by the Engineer within four weeks of the date when the Contractor first takes over the site.

The Contractor will provide all necessary MLSS (Members of Lower Service Staff) for the field office, including day and night Security Guards and a Tea Boy. The Contractor will also provide a competent Computer Operator for office work. Staff considered unsuitable by the Engineer shall be replaced straight away.

The Contractor shall arrange for the field office to be properly cleaned regularly and for access roads and hard standings to be maintained in a well-drained and trafficable condition. All furnishings and fittings in the field office shall also be maintained by the Contractor in good working condition and to the satisfaction of the Engineer.

All materials recovered from dismantling the office and removing access roads, hard standings etc. should be stockpiled on site as directed by the Engineer and all furniture and fittings will be the property of the Employer.

Wherever suitable buildings are available within the general limits of the site of the works, the Contractor may also propose to the Engineer that the buildings be rented. The buildings must conform to all the criteria above and if deemed to be satisfactory, the Engineer may accept that to be used as his office.

1.3.2 Sanitation

The Contractor shall provide adequate water-borne sanitation; refuse collection and disposal arrangements complying with the existing laws of Bangladesh and local by-laws to the satisfaction of the Engineer for all office, laboratory, workshop, rest house, etc. erected on the Site.

1.3.3 Office Equipment and Consumables

The Contractor shall provide and maintain essential office equipment such as Photocopy Machines, Computers, Printers, Internet Devices, etc. for the Engineer's Office as listed in Particular Specifications, Clause 1.2.3 in Section 7 of Volume 1-The Tender. Equipment supplied will be subject to the approval of the Engineer. The Contractor shall supply all consumables related to the equipment and arrange for their proper

maintenance including servicing as recommended by their manufacturers. Upon completion of the Works or as otherwise instructed by the Engineer, all equipment shall be the property of the Contractor.

The Contractor shall also provide and maintain in good working condition, as applicable, all items of kitchen equipment listed in Particular Specifications Clause 1.2.3 in Section 7 of Volume 1-TheTender.

The Contractor shall provide all standard stationery items to the Engineer's field office along with kitchen and bathroom consumables as may be required by the Engineer throughout the duration of the contract.

1.3.4 Sign Boards

The Contractor shall provide identification sign boards of the number and size stated in Particular Specifications, Clause 1.3.4 in Section 7 of Volume 1, The Tender and maintain them in good condition. All information on the signboards will be written in English and Bangla. The signboards will be positioned as directed by the Engineer. The Contractor shall submit proposals for the materials of the signboards, the text layout and installation of the signboards to the Engineer for approval. Each sign shall-clearly show:

- Name of the Project;
- Name of the Employer;
- All other details as required by the Engineer.

The Contractor shall remove the sign boards on completion of the works or as instructed by the-Engineer.

1.3.5 Survey Equipment

The Contractor will be required to provide Survey Equipment for the use of the Contractor's and Engineer's staff. The Specification of the main items required is given in Sections 1.3.5.1 to 1.3.5.3. The numbers of each item to be provided are stated in Particular Specifications, Clause 1.3.5 in Section 7 of Volume 1-The Tender. The Contractor shall provide manufacturer's published specifications of the proposed survey equipment for the approval of the Engineer and shall ensure that equipment supplied to the Site is maintained in good working order.

In addition to the survey equipment specified in Sections 1.3.5.1 to 1.3.5.3, the Contractor shall supply miscellaneous tools and minor items of survey equipment such as 30 m and 3 m long steel tapes, ranging rods, spirit levels, plumb bobs, umbrellas, hammers, knives, wooden stakes, steel pins, string lines, paint, marking crayons, etc. to be used at Site. These shall be available in reasonable quantities at all times for use.

Ranging rods shall be 1.8 m long with alternate red and white painting. They shall be true and straight with a steel pointed tip on one end.

The Contractor shall supply the required number of manpower to the Engineer to assist with the survey and setting out works as and when required.

On completion of the Works or as otherwise instructed by the Engineer, all survey equipment shall be the property of the Contractor.

1.3.5.a Levels and Levelling Staffs

Levels shall be auto set in carrying cases, complete with centering tripods with extension legs, and to the following minimum specifications:

Magnification 32 times	Stadia 1:100
Aperture 40mm minimum	Resolving power 3" (sec)
Angular field of view 1° 20'	Range of sensitivity ± 15 minutes or less
Short Focusing Distance 1m	Horizontal circle diameter 75 mm
Addition constant 0	Graduation 10 minutes
Accuracy ± 1 mm for 1 km double run	
Staffs shall be telescopic, aluminum with graduations in Metric units.	

1.3.5.b Theodolites

Theodolites shall be double circle Triangulation Theodolites with optical Micrometers. The instruments shall be in airtight metal/wooden carrying cases with tool compartments and eyepiece filters complete with centering tripods and extension legs, to the following minimum specifications. One or more Theodolites suitable for the attachment of an EDM may be required.

Objective aperture 45 mm	Addition constant 0
Shortest focusing distance 1.7 m	Sensitivity of collimation level 20"/2 mm
Multiplication constant 100	Graduations 360°

1.3.5.c Electronic Distance Measurer (EDM)

EDM's shall be supplied with full accessories including legs, reflectors and stands, rechargeable batteries and charger and shall be to the following minimum specification.

Distance measurement:	Range not less than 1500m
	Accuracy $\pm (5 \text{ mm} = 5 \text{ pmm}) \text{ mse}$
Telescope:	Image/Mag:m Erect 30 X
	Min focus 1.5 m
Angle Measurement:	Method: Electronic or Optical
	Direct Reading to 5"

Automatic Vertical Index:	Range $\pm 5'$ Setting Accuracy $\pm 0.25''$
Weight including case:	Less than 15kg

1.3.6 Insurance of Engineer's Field Office, Furniture and Equipment

The Contractor shall insure the Engineer's field office, furniture, office equipment and survey equipment against loss or damage by accident, fire or theft for the whole duration of the Contract.

1.3.7 Progress Photographs

Each month on a date to be agreed with the Engineer, the Contractor shall arrange to take a series of not less than 20 and not more than 40 color photographs and will keep record of the progress of the Works.

Two complete sets of prints of approximate size 175 mm x 125 mm with soft copy shall be supplied to the Engineer by the Contractor within one week of each series of photographs being taken. A list shall accompany the photographs, indicating the date when the photographs were taken and a short description of the photographs, against the soft copy numbers.

The photographs shall be taken by an approved professional photographer, accompanied by representatives of the Engineer and the Contractor. If, for any reason, the Engineer is not satisfied with any of the photographs, the Contractor shall arrange at his cost for further photographs to be taken.

1.3.8 Measurement and Payment

The supply of materials and construction of field office for the Engineer, including all furniture and fittings, supply of consumables, access roads, car parking shades etc., and the provision of water, electricity and sewerage facilities and the removal of the field office at the end of the Contract, as described in Specifications Sections 1.2.1 and 1.2.2 and Particular Specifications Clause 1.2.1 in Section 7 of Volume 1-The Tender, shall be paid for at a lump sum price.

The maintenance, cleaning and security of the field office for the Engineer, the provision of MLSS, Tea Boy, and provision of a computer operator and the cost of water, electricity and sewerage shall be paid for at a monthly rate.

The provision of office equipment, consumables and insurance, as described in Specifications Sections 1.2.3 and 1.2.6 and Particular Specifications Clause 1.2.3, shall be paid for at a monthly rate.

Payment for the provision, maintenance and removal of sign boards, as described in Specifications Section 1.2.4 and Particular Specifications Clause 1.2.4 in Section 7 of

Volume 1-The Tender, shall be on a Lump Sum basis.

Payment for the provision, maintenance and insurance of survey equipment and the provision of approval personnel, as described in Specifications Sections 1.2.5 and 1.2.6 and Particular Specifications Clause 1.2.5 in Section 7 of Volume 1-The Tender, shall be at a monthly rate.

Payment for the provision of progress photographs as described in Specifications Section 1.2.7 shall be at a monthly rate.

Pay items shall be:

1/3/1	Supply, Erect and Remove Field Office for the Engineer	Lump Sum
1/3/2	Maintenance, Staffing, Security and Cleaning of the Field Office for the Engineer	Month
1/3/3	Provision of Office Equipment and Consumables	Month
1/3/4	Provision, Maintenance and Removal of Sign Boards	Lump Sum
1/3/5	Provision and Maintenance of Survey Equipment	Month
1/3/6	Provision of Insurance for the Engineer's Office, Furniture and Equipment.	Month
1/3/7	Progress Photographs	Month

1.4 Testing of Materials

1.4.1 Contractor's Site Laboratory

The Contractor shall provide and maintain a site laboratory for the use of the **Contractor** and the Engineer including furniture, testing equipment and consumable stores necessary to carry out the tests listed in Particular Specifications, Clause 1.3.1 in Section 7 of Volume 1-The Tender.

The Laboratory shall be constructed with a reinforced concrete floor (minimum thickness 150mm) and brick walls. The building shall be watertight and provided with electricity, potable running water and sewerage connections. The location of septic tank and soak-away is to be approved by the Engineer. Doors shall be fitted with approved locks and windows shall be provided with mosquito screens and blinds and shall have interior

locking-devices.

Before construction, the Contractor shall submit for the approval of the Engineer, plans and drawings of the proposed laboratory indicating location, overall size, construction details and layout of benches, washing facilities, furniture, testing equipment, sample storage, etc. The Engineer may require revision of the plans prior to giving approval for the construction. The Contractor shall also submit details of the proposed Testing Equipment, furniture and fittings to the Engineer for approval.

It will be the contractor's responsibility to ensure that all the laboratory equipment are duly calibrated as per required frequency from an competent agency and the current calibration charts are available in the laboratory for Engineer's inspection at all times.

The Contractor shall maintain the laboratory, furniture, fittings and testing equipment for the duration of the Contract and replace any part or item that is irreparably damaged or lost. The Contractor shall pay all expenses in respect of water, electricity and other consumables necessary for the running of the laboratory and shall arrange for the laboratory to be properly cleaned regularly.

The Contractor shall not be permitted to commence on-site testing of permanent works until the Site laboratory is complete in all respects unless temporary testing procedures proposed by the Contractor have been approved by the Engineer.

At the end of the Contract, all materials recovered from dismantling the laboratory together with all furniture, fittings and testing equipment shall be the property of the Contractor.

1.4.2 Materials Testing by Independent Laboratories

In addition to the Site testing facilities described in Specifications Section 1.3.1 and Particular Specifications Clause 1.3.1, in Section 7 of Volume 1-The Tender, the Contractor shall be responsible for arranging for the field and off-Site laboratory tests listed in Particular Specifications Clause 1.3.2, in Section 7 of Volume 1-The Tender, and all other tests indicated as the responsibility of the Contractor in Sections of Divisions 2 to 6 of the Specifications. These should be performed by testing laboratories, for example BRRL, BUET or other places as approved by the Engineer. The Contractor shall be responsible for the attendance of the staff from these approved testing laboratories including, if necessary, the provision of transport for personnel, equipment and test-specimens.

1.4.3 Special and Additional Testing

In addition to the testing described in Specifications Sections 1.3.1 and 1.3.2, the Engineer may require further testing to be carried out. Such special and additional testing shall be arranged by the Contractor under the direction of the Engineer.

1.4.4 Staff for Materials Testing

The Contractor shall provide qualified laboratory/material engineers, technicians, assistants, laborer, etc. to carry out sampling and testing of materials in accordance with Specifications Sections 1.3.1, 1.3.2 and 1.3.3. Employing laboratory staff shall be subject to the approval of the Engineer and shall be available to assist the Engineer with sampling and testing as and when required.

1.4.5 Sampling and Testing

The frequency of test requirements for pavement layers, bitumen and concrete mixes should comply with those in Table 1.4-1.

Table 1.4-1 Frequency of Tests

Item	Washed Grading (STP 3.3/7.2)	Atterberg Limits (STP 3.2)	Max Dry Density/ CBR (STP 4.3/4.5, 5.1)	In-situ Density (STP 6.2)	ACV, 10% Fine, LAA (STP 7.7.1, 7.7.2, AASHTO T96)
Earthworks	-	1/2000 m ³	1/2000 m ³	1/1000 m ²	-
Improved Sub-Grade	1/1000 m ³	1/1000 m ³	1/1000 m ³	3/1000 m ²	-
Sub-Base	1/750 m ³	1/750 m ³	1/750 m ³	3/1000 m ²	1/2000 m ³
Base	1/500 m ³	1/500 m ³	1/500 m ³	3/1000 m ²	1/1000 m ³

For Bituminous and Concrete Mixes 1 set of tests per 100 cum of aggregate for shape (STP 7.3), grading (STP 7.2), ACV, 10% Fines and Los Angeles Abrasion Value (STP 7.7.1, 7.7.2 and AASHTO T96) should be carried out. If crushed gravel is used as coarse aggregate, percentage of fractured faces shall be checked 1 test per 100cum.

Water absorption, Soundness and Coating & Stripping Test should be carried out 1 test for each source/type of aggregate at the start of work and subsequently on every change in quality of aggregate. Sand Equivalent Value for the fine aggregate for bituminous mixes shall be determined for minimum 1 test /100 cum.

Grading of filler (STP 7.2) for bituminous mixes should be checked 1 test/20 tons of filler. Water Sensitivity Test should be carried out on the bituminous mixes as per AASHTO-T283 at the time of mix design and subsequently as and when required by the Engineer.

Dynamic cone Penetrometer (DCP) and Plate Load Test to determine deformation modulus E_v2 and E_v1 (ASTM 1195/ASTM 1196 and DIN 18134) should be carried out in addition to the density test for each layer of Embankment and Sub-grade 1 test /1000 Sqm. Testing for E_v2 and E_v1 is mandatory; however, it's important to note that the test results will not be used as acceptance criteria but solely for record keeping purpose.

The Contractor shall maintain complete records of test results, which may be inspected by the Engineer at any time. All test results shall be recorded on standard forms approved by the Engineer and shall be signed by the Contractor's engineer or technician in charge of the laboratory. Completed forms shall clearly show the locations of samples, sampling dates and testing dates. Samples shall be numbered serially at the time of sampling. A copy of all test results should be submitted to the Engineer immediately after completion of the test.

The Engineer will be informed prior to any sampling or testing carried out in the laboratory and will have the right to use the facilities and equipment to make his own tests. The Contractor shall have the right to witness any sampling or testing carried out by the Engineer. On completion of the Contract, the original copies of all test results shall be handed over to the Employer through the Engineer.

1.4.6 Measurement and Payment

The provision of the laboratory, furniture, equipment and services detailed in Specifications Section 1.3.1 and Particular Specifications Clause 1.3.1, in Section 7 of Volume 1-The Tender, and the removal of the laboratory, furniture and equipment at the end of the Contract shall be paid for at a lump sum price. Maintenance of the site laboratory, furniture and equipment shall be paid for at a monthly rate.

The sampling and testing carried out by the Contractor in accordance with Specifications Sections 1.3.1, 1.3.2, 1.3.4 and 1.3.5 shall be deemed to have included in the pay items for the respective work in Divisions 2 to 6 of the Specifications.

Payment for special or additional tests described in Specifications Section 1.3.3, shall be under a provisional sum, unless the costs of such tests are to be borne by the Contractor in accordance with Clause 35.4 of Volume 2, the Conditions of Contract.

Pay items shall be:

1/4/1	Provide and Remove Site Laboratory and Equipment	Lump Sum
1/4/2	Maintain Site Laboratory	Month
1/4/3	Special or Additional Tests	Provisional Sum

1.5 Transport for The Engineer

1.5.1 General

The Contractor shall provide and maintain road and river transport for the exclusive use of the Engineer, his representatives and representatives of the Employer.

1.5.2 Items of Transport

Road transport, which shall be used both on and off the Site, shall include saloon cars of 1200 cc capacity, double cabin pick-ups, and four-wheel drive vehicles with a minimum of 6 seats and motor cycles of 125 cc capacities.

River transport shall be motor boats of minimum length 5 m suitable for carrying out survey and inspection work and shall have a covered deck area to give protection from the sun and rain. No one either from the Engineer or from the Contractor other than the authorized boatman shall be allowed to operate the boats.

The Bill of Quantities indicates the requirements for road and river transport. When items of transport are out of use for repairs, servicing etc., the equivalent substitutes shall be provided by the contractor.

Items of transport and drivers/boatmen considered unsuitable by the Engineer shall be replaced.

1.5.3 Measurement and Payment

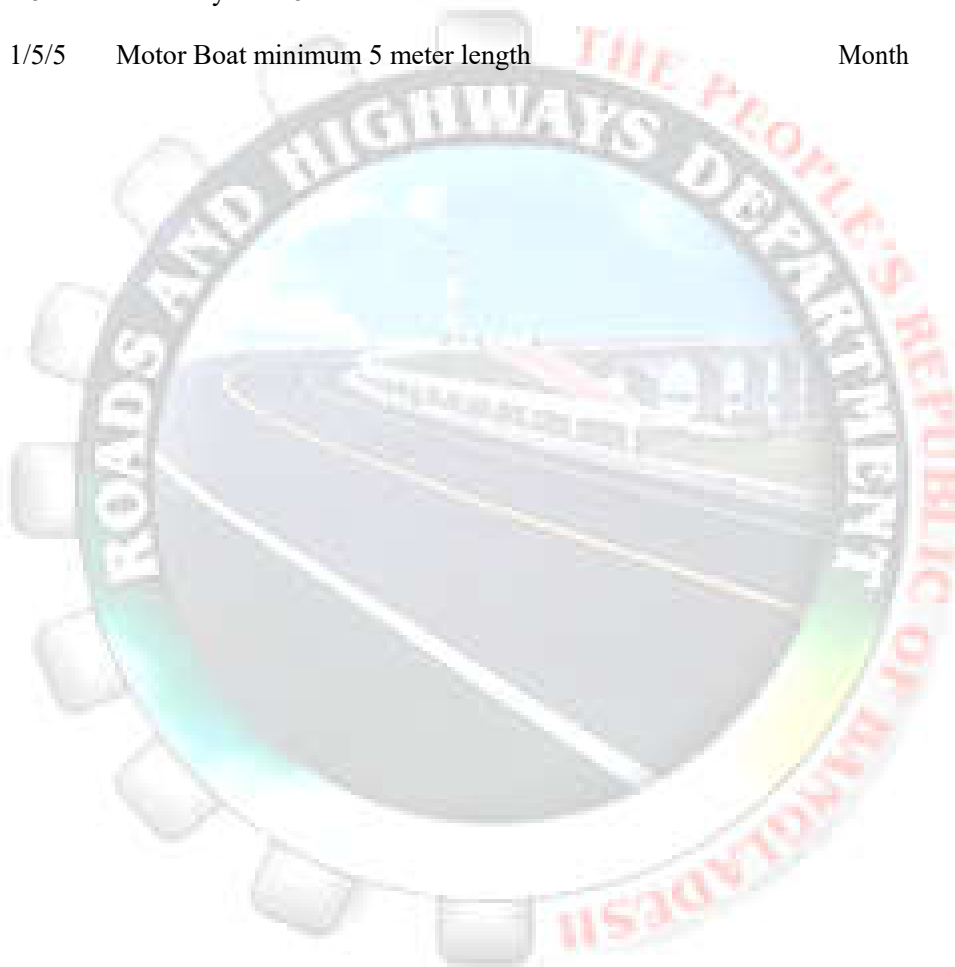
The Contractor's monthly rate for the provision and maintenance of vehicles and motor cycles shall include fuel, servicing, maintenance, drivers' wages, taxes, duties, registration, insurance, etc., as applicable under the current law of the Government of Bangladesh.

The Contractor's monthly rate for the provision of motor boats shall include fuel, servicing, maintenance, boatmen's wages, taxes, duties, registration, insurance, etc. as applicable under the current law of the Government of Bangladesh.

All boats shall be provided with life belts, life jackets and navigational and warning lights.

Pay items shall be:

1/5/1	Saloon Car 1500 cc Capacity	Month
1/5/2	Pick-up (Double Cab)	Month
1/5/3	Four Wheel Drive Vehicle minimum 6 seats	Month
1/5/4	Motor Cycle 125 cc	Month
1/5/5	Motor Boat minimum 5 meter length	Month



1.6 Relocation of Public Utilities

1.6.1 Description

The Contractor shall be responsible for establishing the locations of all public utilities within the Site of the Works and for their protection. Where the necessity for permanent relocation of public utilities has been identified, details of which shall be outlined on the Drawings.

Should the Contractor consider that the temporary relocation of public utilities is necessary in order to carry out the Contract works without obstructions, he shall submit details of his proposals to the Engineer.

Relocation works will normally be undertaken by the concerned authorities, with which the Contractor will be expected to liaise. The Contractor shall indicate relocation works in his Contract Program.

1.6.2 Measurement and Payment

The Contractor should include all costs associated with the location and protection of public utilities and the temporary relocation of public utilities in his pricing.

Payment for the necessary permanent relocation of public utilities will be under a provisional sum.

Pay items shall be:

1/6/1 Relocation of Public Utilities

Provisional Sum

1.7 Contractor's General Obligations

1.7.1 Site Establishment, Maintenance and Demobilization

The Contractor shall be liable for the provision, maintenance and removal at the end of the Contract of all offices, stores, covered workshops, canteens, toilet facilities, etc., required to execute the Works in accordance with the Contract Documents. In addition, the Contractor shall be responsible for complying with his obligations for safety, security and protection of the environment described in the Contract Documents including in Sub-Clauses 17.1 and 18.1 of Volume 2-Conditions of Contract.

1.7.2 Provision of Performance Security

This item is for the provision by the Contractor of the Performance Security, the requirements of which are stated in Clause 43 of Volume 2-Conditions of Contract.

1.7.3 Provision of Insurances

This item is for the provision of insurances as required in accordance with Clauses 11, 13 and 53 of Volume 2-Conditions of Contract. The minimum amount of third-party insurance shall be as stated in the Particular Condition of Contract in Section 4 of Volume1-The Tender. Failure to provide insurance will result in no interim payments.

1.7.4 As-Built Drawings

The Contractor shall furnish sets of as-built Drawings of the Works to the Engineer, showing the permanent works as actually constructed, within one month of completion of the Works. Included in the sets of as-built Drawings there will be revisions of Tender Document and Drawings supplied to the Contractor, if any, during the Contract as well as revisions of drawings supplied by the Contractor for the Contract. The As-built drawings submitted by the Contractor will be subject to the approval of the Engineer. For specific requirements for the As-built Drawings refer to Particular Specifications Clause 1.6.4 in Section 8 of Volume 1-The Tender.

1.7.5 Measurement and Payment

Payment for these items shall be included by the contractor in his rates for the Works

unless otherwise provided for in Clause 25 of the Contract Data in Section 4 of Volume 1-
The Tender.





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2.1 CLEARING AND GRUBBING

2.1.1 Description

This work shall consist of all clearing and grubbing necessary for the performance of the work covered by the Contract in accordance with the Specifications.

The clearing and grubbing shall in more detail consist of clearing the designated areas of all trees, down timber, vegetation, rubbish and any other objectionable materials and shall include grubbing roots and stumps and disposing of all material resulting from the clearing and grubbing. It shall also include the demolition, removal and disposal of structures that obstruct the Works except where provided for in Section 2.9.

Clearing shall be confined to the areas enclosed by the right-of-way limits. Grubbing shall be confined to areas covered by the Works.

2.1.2 Preservation of Property

Attention is directed to the Contractor's obligations under the Contract with regard to damage, particularly with regard to protection of property, gardens and landscape and to responsibility for damage claims. Existing roads, improvements, facilities, adjacent property, utilities, services and trees and plants designated for preservation shall be protected from injury or damage which could result from the Contractor's operations.

2.1.3 Construction Methods

2.1.3.a Clearing

Clearing shall consist of the removal and disposal of everything above ground level including overhanging branches except those things the Engineer directs are to be left undisturbed. The material to be cleared shall include but not necessarily be limited to trees, stumps, logs, brush, undergrowth, grass, crops, loose vegetable matter and structures unless provided for elsewhere. Trees and stumps shall be cut to ground level.

Clearing shall also include the removal of existing fences, remnants of buildings and courtyard pavements etc.

The roadway and adjacent areas shall be left with a neat and finished appearance. No accumulation of inflammable material shall remain on or adjacent to the right-of-way.

2.1.3.b Grubbing

The original ground surface shall be disturbed as little as possible. Grubbing shall, therefore, be confined to major roots beneath the embankment, ditches, canal diversions and footing excavations. In these areas grubbing shall consist of the removal of all major stumps, embedded logs, tree roots and other material, except as otherwise directed by the Engineer. Holes left shall be filled with suitable material compacted to comply with Section 2.6 of the Specification with the cost of this being included in the rate for grubbing. Topsoil shall be

removed as agreed with the Engineer and will be measured as roadway excavation. Grubbing beneath the embankment shall be at the direction of the Engineer.

In agricultural areas where the ground has been formed into ridges or dikes, the ground shall be roughly levelled or graded to form a surface suitable for embankment foundation to the satisfaction of the Engineer.

2.1.3.c Ownership of Cleared Material

All cleared material shall, unless otherwise provided for in the Contract, be the property of the Employer. Materials shall be stockpiled, or placed, by the contractor on site in a location agreed by the Engineer.

2.1.3.d Existing Drainage

Existing ditches, drainage channels etc., shall be closed at the embankment foundation boundary except where pipes or other structures are prescribed. Disused drains below embankments shall be removed and trenches filled in accordance with Section 2.4.

The Contractor is responsible for undertaking any provisional drainage measures, including temporary watercourses and ditches, which may be necessary.

2.1.4 Measurement

Neither the work of clearing nor grubbing disposal sites, material sites, nor imported borrow pit sites shall be paid for when such sites are outside the areas designated for clearing or grubbing and the Contractor is permitted to exercise his own option as to whether he elects to use such disposal sites or borrow pit sites.

Removal and uprooting of tree having girth size less than 300 mm shall not be measured and shall be included in measurement of clearing and grubbing. Removal and uprooting of trees of girth sizes greater than 300 mm shall be measured.

2.1.5 Payment

Clearing and grubbing will be paid by area. The payment shall be full compensation for furnishing all labour, materials, tools, equipment and incidentals necessary for the clearing and grubbing the designated areas as specified in these Specifications or as directed by the Engineer including the removal and disposal of all resulting material.

“Removal and uprooting of trees shall be paid in Number of different girth sizes mentioned in Pay Items. The rate for removal and uprooting of trees shall include all cost of cutting, dressing, uprooting, grubbing and carriage to stockyard designated by the Employer.”

Pay items shall be:

2/1/1	Clearing and Grubbing	Square Metre
2/1/2a	Remove and uproot trees (Trees with girth 300 mm to 800 mm)	Number
2/1/2b	Remove and uproot trees (Trees with girth 801 mm to 1500 mm)	Number
2/1/2c	Remove and uproot trees (Trees with girth beyond 1500 mm)	Number



2.2 ROADWAY EXCAVATION

2.2.1 Description

The work shall consist of all the required excavation within the limits of the right of way unless covered by other Sections of these Specifications. This shall include excavation of side ditches, where required, the removal, hauling and proper utilisation or disposal of all excavated materials and shaping of excavation and preparation of exposed surfaces of excavation on the entire length of the roadway, in accordance with these Specifications and to the lines, levels, grades, dimensions and cross sections shown on the Drawings or as required by the Engineer. The works specified shall also include operations in part widths and small areas of roadway where directed by the Engineer without any extra cost to the Employer.

Roadway excavation shall include the following:

- a) All excavation indicated on the Drawings within the limits of the cross sections and excavation of all materials for side roads and intersections.
- b) The removal of existing pavement, sidewalks, kerbs and gutters within the limits of construction.
- c) Excavation for stream and channel changes where not covered under Section 2.4, Channel Excavation.
- d) Excavation required in cuts under embankments below the lowest normal limit of excavation indicated on the Drawings or below ground line and for the removal of unsuitable material.

Where the existing pavement and/or shoulders are ordered to be scarified and recompacted, this work shall be carried out and paid for in accordance with the provisions of Section 3.1.3.

2.2.2 Materials

Materials from roadway excavations shall be classified as suitable or unsuitable as fill material, or as road pavement material, by the Engineer. To be suitable as fill material, soil must not contain roots, sods or other deleterious materials and must conform to the requirements of Section 2.6.2.

Material excavated from existing road pavements which are to be reconstructed may be used in the new road pavement provided the material after suitable breaking and mixing satisfies all requirements of these Specifications.

The existing pavement materials which will include, but not be restricted to bituminous surfacing, bricks and brick materials, stone, concrete and concrete materials, need not in themselves comply fully with the Specifications for the intended use but should be of such quality to allow the Specifications to be met after breaking, processing and if necessary

mixing with better quality materials. Existing pavement materials containing an excess of clay, soil or organic material will not normally be considered suitable for reuse in the new pavement. Fine sands which may be found under some pavements shall not be considered as part of the road pavement but shall be classed as material suitable for use as fill.

Deduction of the value of excavated pavement material under Pay item No. 2/2/6 shall not qualify it as suitable for reuse in the Works. Acceptability of the material (after processing as the case may be) shall be determined by the Engineer and only such material shall be permitted for incorporation in the permanent works that fully satisfies these Specifications in all respect.

2.2.3 Construction Methods

2.2.3.a General

All roadway excavation and embankment construction shall be performed as specified here and in Section 2.6 (Embankment), and the excavation as well as the completed roadway shall conform to the required alignments, levels, grades and cross sections. Prior to the commencement of any work, cross sections and measurements should be taken of the undisturbed roadway. Excavated material shall be deposited so as not to cause damage to services or property and so as to cause no impediment to the drainage of the site or surrounding area.

2.2.3.b Excavated Material Used in the Works

Suitable soil from the roadway excavation shall be used so far, as is practicable as fill or top soil material.

Suitable excavated material, if it is to be reused for the Works, shall be temporarily stockpiled in suitable and safe areas approved by the Engineer and properly protected from any damage or loss.

2.2.3.c Unsuitable Material from Roadway Excavation

Excavated material classified as unsuitable as fill material and excavated road pavement material not approved by the Engineer for use in the new road pavement shall be known as waste. It shall be the property of the Employer. The Contractor shall stockpile, or place the material in a location approved by the Engineer.

2.2.3.d Excess Suitable Excavated Material

Suitable material from approved roadway excavation which is in excess of that required for construction of any part of the Works shall be the property of the Contractor, and it may be shifted/disposed of by the contractor with prior intimation to the Engineer.

2.2.3.e Excavation of Unsuitable Soil

Unsuitable soil shall be excavated below subgrade level in cut and below embankment foundation level to the depth shown on the Drawings or as directed by the Engineer. The

excavation shall be backfilled in accordance with Section 2.6 of the Specifications where unsuitable soil is excavated below the normal subgrade level or below embankment foundations or for benching under embankments.

2.2.3.f Slopes

All slopes shall be finished in a neat and workmanlike manner as shown in the drawings or as directed by the Engineer and to an accuracy appropriate to the material, and care shall be taken that no material is loosened below the required slopes.

2.2.3.g Drainage

During construction, the roadbed and ditches shall be maintained in such condition as to ensure proper drainage at all times.

Any ditches and channels temporarily required shall be constructed and maintained as to avoid damage to the roadway section.

2.2.3.h Preparation of Excavated Areas

The surfaces of all excavated areas shall be neat and workmanlike and shall have the required forms, super elevations, levels, grades and cross sections. The surfaces shall be constructed to the required accuracy to permit the construction of subsequent layers of material as specified in Section 2.6 and other Sections of these Specifications. The surface tolerance shall be ± 25 mm from the specified levels at any point.

2.2.4 Measurement

All required and accepted roadway excavation including excavation of suitable soil, unsuitable soil and existing road pavement shall be measured separately in cubic metres by the average end area method as computed from the initial (prior to excavation) and final (post excavation) roadway cross sections. For the purpose of measurement all the material except structures and pavement materials shall be considered as soil.

Preparation of excavated areas will not be measured and paid for separately as this is included in the excavation work. Measured roadway excavation shall include removal of slides, breakages and cave-ins except where caused by carelessness or improper methods of the Contractor.

2.2.5 Payment

The quantities of roadway excavation in pavement, suitable soil and unsuitable soil measured as specified above will be paid for at the respective unit price per cubic metre under the Contract. The price shall include all labour, materials, tools, equipment and incidentals to complete the work of excavation and stockpiling or disposal at locations approved by the Engineer, including shaping and preparation of all excavated surfaces and working in small areas if necessary.

The value of suitable soil recovered from Roadway excavation shall be deducted from payments due to the Contractor. It shall be determined by multiplying the total quantity of

suitable soil measured in accordance with Section 2.2.4 by the rate inserted by the Contractor against pay item 2/2/5. No consideration shall be given to whether the whole quantity of recovered suitable soil could be reused or not in the Works.

The value of the recovered pavement material shall also be deducted from payments due to the Contractor. It shall be determined from the total quantity of pavement material measured in accordance with Section 2.2.4, multiplied by the rate inserted by the Contractor against pay item 2/2/6. No consideration shall be given to whether the whole quantity of excavated pavement material was determined suitable or not by the Engineer, and also to whether it could be reused in the works or not.

The measured quantity of recovered pavement material or suitable soil shall include no allowance for losses during excavating, transporting, mixing, stockpiling, processing and compaction or for pilferage for the purpose valuation of respective deduction amount.

The pay items in this section of the specifications for roadway excavation shall be full compensation for all work involved in performing the roadway excavation as shown on the drawings and as directed by the engineer, including the cost of temporary stockpiling, selecting and protecting the materials to be reused and the cost of disposal of unsuitable/excess suitable material.

Pay items shall be:

2/2/1	Roadway Excavation in Unsuitable Soil including stockpiling or disposal in a location agreed by Engineer.	Cubic Metre
2/2/2	Roadway Excavation in Suitable Soil including stockpiling on Site	Cubic Metre
2/2/3	Roadway Excavation in Existing Pavement (Bituminous, Brick, Stone, Unreinforced Concrete and other Materials Except Reinforced Concrete).	Cubic Metre
2/2/4	Roadway Excavation in Existing Reinforced Concrete Pavement	Cubic Metre
2/2/5	Deduction for Value ¹ of Suitable Soil Recovered from Existing Road.	Cubic Metre
2/2/6	Deduction for Value ² of Pavement Materials Recovered from Existing Road.	Cubic Metre

Note:

1. Quantity for item no. 2/2/5 shall be taken equal to that of item no. 2/2/2.
2. Quantity for item no. 2/2/6 shall be taken equal to that of item no. 2/2/3.

2.3 BORROW

2.3.1 Description

This work shall consist of the clearing and stripping of borrow pits, the excavation and hauling of materials obtained from approved sources using the material from borrow pits for constructing embankment, backfill, subgrade, shoulders and other parts of the work as required under the Contract or by the Engineer.

This Section applies to borrow whether from borrow pits within or outside the right-of-way.

2.3.2 Acquisition and Use of Borrow Pits

2.3.2.a Borrow Pits within the Right-of-Way

The use, depth, location, and dimensions of borrow pits within the right-of-way shall be subject to the approval of the Engineer. The Contractor will have to be satisfied himself before entering into the Contract as to the use of borrow pits within the right-of-way and to have allowed in the rates for the risk of borrow pits not being permitted in areas of uncertainty. Notwithstanding any general advice given by the Employer or the Engineer before the submission of tenders, borrow pits may be prohibited, or restricted in dimensions and depth by the Engineer where:

- a) They might affect the stability or safety of the highway, the railway or structures.
- b) They might interfere with natural or artificial drainage or irrigation.
- c) They might interfere with adjoining property or future expansion plans for the highway.

2.3.2.b Borrow Pits Outside the Right-of-Way

The Contractor may open borrow pits outside the right-of-way and in such cases the Contractor shall be fully and solely responsible for the expenses incurred and any legal consequences.

2.3.3 Construction Methods

All suitable materials removed from borrow sources shall be used as indicated on the Drawings or as directed by the Engineer. During construction the borrow pits shall be

kept drained as far as practicable and the work shall be carried out in a neat and workmanlike manner.

Sites of the borrow operations shall be left in a suitable and slightly condition such as to provide proper drainage where practicable.

2.3.4 Measurement and Payment

No payment will be made to the Contractor for borrow and as such it shall not be measured. Payment under the items of the work in which the borrow material is placed shall be full compensation for all the necessary tasks and activities to acquire, to provide and place the material.

2.4 CHANNEL EXCAVATION

2.4.1 Description

This work shall consist of excavation for channels for discharging water from side ditches where shown on the Drawings, required in the Specifications or as directed by the Engineer. The work shall include the proper utilisation and hauling or disposal of all excavated materials, and constructing, shaping and finishing of all earthworks.

2.4.2 Materials

Excavated materials shall be classified as unsuitable and suitable soil. To be suitable as fill material the soil must not contain muck, roots, sods or other deleterious materials and must conform to the requirements of Section 2.6.2.

2.4.3 Construction Methods

2.4.3.a Alignment and Levels

Channel work shall be constructed in a neat and workmanlike manner correct to alignments, levels, grades and cross sections required on the Drawings, in the Specifications or by the Engineer.

2.4.3.b Excavation

Deepening and realignment of existing canals and channels shall be carried out in a way to allow free flow of the water.

During excavation of new channels these shall as far as possible be kept drained.

All suitable materials removed from the excavation shall be used as far as practicable in constructing the roadway.

2.4.3.c Filling of Obsolete Channels

Any obsolete canals and channels within the embankment area shall be cleaned up and back filled with sand to obtain sufficient stability. When sand fill is at a level of 500 mm above water level, compaction shall be carried out as specified in Section 2.6.

2.4.3.d Unsuitable Excavated Material

Excavated material from channel excavations classified as unsuitable as fill material by the Engineer shall be known as waste. The Contractor, shall stockpile, or place the material in a location approved by the Engineer.

2.4.3.e Excess Suitable Excavated Material

Suitable material from channel excavation, which is in excess of that, required for construction of any part of the Works shall be the property of the Employer and shall be stockpiled on Site as instructed by the Engineer.

2.4.4 Measurement

Payment for backfilling existing channels shall be in accordance with Section 2.6.

Quantities of channel excavation in unsuitable material shall be measured in cubic metres determined by average end area methods computed from the original and final geometric cross sections of the authorised and completed excavation.

Excavation of channel in suitable material shall not be measured for direct payment. The cost shall be included in the rates for the items of the Works in which the excavated material is placed. The exception to this is excess suitable material which is stockpiled on Site.

Measured channel excavation shall include for the removal of any slides and cave-ins which occur in channels except where these have been caused by carelessness or the use of improper methods by the Contractor.

2.4.5 Payment

This work measured as provided above shall be paid for at the Contract unit price per cubic metre. The payment shall be full compensation for all excavation, for maintaining free flow in the channel where necessary and for all labour materials, tools, equipment and incidentals necessary to complete the work, including stockpiling or disposal off Site.

Channel excavation of material which is suitable for embankment fill shall not be paid for separately but shall be paid for at the rate for fill from land as provided for in Section 2.6.

Pay items shall be:

2/4/1 Channel Excavation in Unsuitable Material

Cubic Metre

2/4/2 Channel Excavation in Suitable Material
including stockpiling on Site (applies to Excess
Suitable Excavated Material only)

Cubic Metre



2.5 EXCAVATION AND BACKFILL FOR STRUCTURES

2.5.1 Description

This work shall consist of excavation in any material for the foundation of structures, other than for pipe culverts, not otherwise provided for in the Specifications; constructing and removing cofferdams, sheeting; pumping, dewatering and bailing; backfilling of completed structures with suitable material and disposal of excavated material. Pipes and manholes shall be excavated and backfilled in accordance with Sections 6.2 and 6.3.

Filling of areas above the natural ground level or above the limits of road excavation or channel excavation is described in Section 2.6.

2.5.2 Materials

2.5.2.a Foundation Fill Material

Material for foundation fill shall consist of suitably graded sand to one of the grading envelopes A to C of Section 2.8.2, gravel or stone as shown on the Drawings or as required by the Engineer, or concrete. Concrete for foundation fill shall conform to the general requirements of Section 5.1. Concrete to be placed under water shall conform to the requirements of Section 5.1.3.14. Concrete used as foundation fill in dry excavation shall be class 15.

2.5.2.b Backfill Material

Backfill materials below top level of pile caps shall consist of sand with not more than 10% of material passing the 75 micron sieve, if not otherwise directed by the Engineer or stated on the Drawings.

Backfill above top level of pile caps but outside embankment and road areas shall be excavated material if suitable and approved by the Engineer.

2.5.3 Construction Methods

2.5.3.a Clearing

Prior to starting excavation operations in any area, all necessary clearing and grubbing shall have been performed.

2.5.3.b Excavation

A) General

The Contractor shall notify the Engineer sufficiently in advance of the beginning of any excavation so that cross section elevations and measurements may be taken of the undisturbed ground. The natural ground adjacent to the structure shall not be disturbed without permission of the Engineer.

Trenches and foundation pits for structures and structure footings shall be excavated to the lines, grades and elevations shown on the Drawings or as directed by the Engineer. The elevations of the bottoms of footings shown on the Drawings are approximate only and the Engineer may order in writing such changes in the dimensions or elevations of footings as may be deemed necessary to secure a satisfactory foundation.

Boulders, logs and other objectionable material encountered in excavation shall be removed. After each excavation is complete the Contractor shall notify the Engineer to that effect and no footings, bedding material or structure shall be placed until the Engineer has approved the depth of excavation and the character of the foundation material.

The foundation material shall be cleared of all loose material and cut to a firm surface, either level or stepped or serrated, as specified or shown on the Drawings or directed by the Engineer.

B) Foundation Directly on the Ground

When the footing is to rest on the ground and not on piles, special care shall be taken not to disturb the bottom of the excavation, and excavation to final grade shall be deferred until just before the footing is to be placed. When, in the opinion of the Engineer, the foundation material is soft or otherwise unsuitable, the Contractor shall remove the unsuitable material and insert foundation fill material or concrete as specified or shown on the Drawings or directed by the Engineer. If foundation fill material is required, it shall be placed and compacted in layers not more than 150 mm thick to the degree of compaction as specified in Section 2.6.

C) Foundation on Piles

When the ground between piles is too soft to support green foundation concrete, the Contractor shall submit his proposals for a bottom form to the Engineer for his approval. Extra excavation and foundation fill or concrete fill in such cases will not be paid for separately.

If the bottom form is achieved by such strengthening of the ground, the Contractor shall, if requested, submit calculations showing that the pile cap will not be harmed during hardening due to differential settlements between the piles and the strengthened ground.

2.5.3.c

Disposal of Excavated Material

Excavated material classified as suitable by the Engineer shall generally be utilised as backfill or embankment fill. Surplus suitable material shall be stockpiled on Site as

described in Section 2.2.3.4 of these Specifications. Excavated suitable material for use as backfill shall be deposited by the Contractor in spoil heaps at points convenient for re-handling of the material during the backfilling operation and approved by the Engineer.

Excavated material classified as unsuitable as backfill by the Engineer shall be carried to waste as described in Section 2.2.3.3 of these Specifications.

Excavated material shall be deposited in such places and in such a manner as not to cause damage to roads, services or property either within or outside the right-of-way and so as to cause no impediment to the drainage of the site or surrounding area. The location of spoil heaps shall be subject to the approval of the Engineer who may require that the reference lines and the traverse lines of any part of the structure be kept free of obstruction.

2.5.3.d

Cofferdams

A) The term “cofferdam” denotes any temporary or removable structure, constructed to hold the surrounding earth, water or both, out of the excavation, whether such structure is constructed of earth, timber, steel, concrete or any combination of these. The term includes earth dikes, timber cribs, sheet piling, removable steel shells and all bracing; and it shall be understood to include excavation enclosed by pumping wells and well points.

The cost of cofferdams is always to be included in the tender rates/prices for the permanent work.

B) The term “caisson” denotes a permanent part of the substructure so constructed as to sink gradually into place as material is excavated within the area protected by its side walls. Where the term “well” is used it shall be taken to have the same meaning as “caisson”.

C) When no provision for caissons is shown on the Drawings, it shall be the intent of the Contract that suitable cofferdams shall be provided for all excavations where cofferdams may be necessary in order to control water to preclude sliding and caving of the walls of the excavation.

D) The Contractor shall submit upon request, drawings showing his proposed method of cofferdam and caisson construction. Approval of the drawings by the Engineer will not in any way relieve the Contractor of the responsibility for the adequacy of the design for strength and stability or for the safety of the people working therein.

- E) The interior dimensions of cofferdams shall be such as to give sufficient clearance for the construction and removal of any required forms and the inspection of the interior and to permit pumping.
- F) If possible, cofferdams shall be so designed that no cross bracing shall be left in place. If this is not possible, bracings left in place shall be of structural steel. The end of such structural members that would be exposed when the structure is completed shall be boxed back at least 50 mm behind the concrete face. The resulting holes shall be completely filled with concrete.
- G) In general, sheet piling cofferdams shall extend well below the bottom of the footing and shall be well braced and as watertight as possible.
- H) When foundation piles are to be driven inside a cofferdam and it is judged impossible to de-water the cofferdam before placing a concrete seal, the excavation may be extended below the designed level to a depth sufficient to allow for swell of the material during pile driving operations. Any material that rises to a level above the design level shall be removed.
- I) Where it is possible to de-water the cofferdam, the foundation material shall be removed to exact grade after the foundation piles are driven.
- J) Backfilling in a foundation to compensate for excavation, which has been extended below the required grade, shall be at the expense of the Contractor. Backfilling shall be with concrete or foundation fill material as indicated on the Drawings, or as directed by the Engineer.

If no material is indicated, backfilling shall be concrete of the same kind as required for the structure to be constructed in the excavation. Unless otherwise permitted no excavation shall be made outside of caissons or cribs or cofferdams or sheet piling and the natural streambed adjacent to the structure shall not be disturbed without permission from the Engineer.

If any excavation or dredging is made at the site of the structure before caissons, cribs, or cofferdams are in place, the Contractor shall after the foundation is in place, backfill all such excavation to the original ground surface or stream bed with material satisfactory to the Engineer.

Material deposited within the stream area from foundations or other excavations or from the filling of cofferdams shall be removed and the stream area freed from obstruction.

- K) Caissons and cofferdams, which have tilted or moved laterally during construction, shall be corrected as necessary at the expense of the Contractor.

L) Unless otherwise provided cofferdams shall be removed after the completion of the sub-structure. The removal shall be effected in such a manner as not to disturb or mar the finished work. The Engineer may order the Contractor to leave any part or the whole of the cofferdam in place.

M) When conditions which, in the opinion of the Engineer, render it impossible to de-water the foundation before placing the footing are encountered, the Engineer may require the construction of a concrete foundation or seal of such dimensions as he may consider necessary, and of such thickness as to resist any possible uplift. The concrete for such seal shall be placed as shown on the Drawings or required by the Engineer. The foundation shall then be de-watered and the footing placed. When weighted cribs are used and the weight is used to overcome partially the hydrostatic pressure acting against the bottom of the foundation seal, special anchorages such as dowels or keys shall be provided to transfer the entire weight of the crib to the foundation seal. When a foundation seal is placed under water the cofferdam shall be vented at low water as directed.

Cofferdams shall be constructed so as to protect newly cast concrete from sudden rising of the water and to prevent damage to the foundation by erosion.

2.5.3.e

Pumping and Bailing

Pumping and bailing from the interior of any foundation enclosure shall be done in such a manner as to preclude the possibility of the movement of water through or alongside any concrete being placed. No pumping or bailing will be permitted during the placing of concrete and for a period of at least 24 hours thereafter unless it is done from a suitable pump separated from the concrete work by a watertight wall or from well points.

Excavations shall be as dry as possible prior to and during placing concrete. Placing concrete under water will only be permitted if indicated on the Drawings or approved by the Engineer.

2.5.3.f

Backfilling

All spaces excavated under these Specifications and not occupied by the permanent structure shall be backfilled. Backfilled material shall fully comply with this Specification and adequate provision shall be made for drainage. No backfilling shall commence until permission has been given by the Engineer.

Backfill under top level of pile caps shall always be made with compacted sand fill free from chemical contamination. Over top level of the pile cap but outside embankment and road areas, the backfill shall be excavated material if suitable and

free from chemical contamination, and approved by the Engineer. If the excavated material is not suitable, the Engineer may order sand filling.

Backfill within the embankment and road areas shall be made in accordance with Section 2.6 of these Specifications.

Special care shall be taken to prevent any unduly high pressure against the structures. In placing backfill and embankment, the material shall be placed insofar as possible to approximately the same height on both sides of the structure at the same time. If conditions require backfilling appreciably higher on one side, the additional material on the higher side shall not be placed until permission is given by the Engineer that the structure has enough strength to withstand any pressure created.

Jetting of fill or other hydraulic methods involving, or likely to involve, liquid or semi-liquid pressure is prohibited. Backfill and embankment fill shall not be placed behind the walls of bridges or box culverts until the top slab has been placed for at least three days.

The placing of embankment and the benching of slopes shall continue in such a manner that at all times there will be a horizontal berm of thoroughly compacted material for a distance at least equal to the height of the abutment or wall to be backfilled.

2.5.4

Measurement

The volume of excavation and backfill shall be measured in cubic metres of excavated undisturbed material.

The quantity of excavation for structures to be measured for payment shall include excavation for all structures except pipe culverts, which will be in accordance with Section 6.2. The measured volume shall be the excavation plan outline, bounded on the bottom by the plane of the underside of the brick flat soling to the blinding concrete under the reinforced concrete footing and on the top by the surface of the existing ground and on the sides by vertical planes of the footings.

Backfilling with previously excavated material shall not be measured or paid for separately but shall be deemed included in the rate for excavation.

Backfill with concrete or sand where directed by the Engineer including concrete seals shall be measured separately as the volume within the plan outline and top and bottom surfaces. Concrete or sand placed to backfill excavation beyond the excavation required will not be measured for payment. The plan outline referred to is the excavation plan outline as defined above.

If sand fill is ordered over top level of pile cap, the fill shall be the specified filling volume measured on the Drawings up to profiles agreed upon in writing by the Engineer.

In the case of structures for which a lump sum price is called for, the volume of excavation as stated above for the work as shown on the Contract Drawings, shall be subtracted from the volume measured as above, and the price to be paid or deducted shall be based on the measured increase or reduction of the excavation shown on the Drawings.

Removal of slides, cave-ins, silting or filling shall not be measured nor paid for.

2.5.5

Payment

This work measured as provided in Section 2.5.4 shall be paid for at the Contract unit prices per cubic metre for each particular item. The payment shall be full compensation for all excavation, stockpiling, backfilling and disposal including compaction; constructing and removing all cofferdams; all dewatering, pumping and bailing; and for furnishing all materials, labour, equipment, tools, sheeting, bracing, cofferdams, pumps, and incidentals necessary to complete the work.

Payment for backfilling shall be included in the pay item for "Excavation and Backfill for Structures" except for sand backfill and concrete backfill. These backfill types shall be measured as provided in Section 2.5.4 and paid for at the concerned Contract unit prices, but no compensation in the pay item "Excavation and Backfill for Structures" shall be made for less backfilling with excavated material or more surplus to waste.

All payment for the backfilling and compaction of those areas which were removed, as structural excavation shall be included in the appropriate unit rates below. Filling or backfilling of areas above the natural ground level or above the limits of road excavation or channel excavation section shall be paid for under Section 2.6.

Cofferdams for structures without excavation, for example for pile caps over water shall be included in the unit prices for the concerned pile cap.

Pay items shall be:

2/5/1 Excavation and Backfill for Structures	Cubic Metre
2/5/2 Concrete Backfill for Structures	Cubic Metre
2/5/3 Sand Backfill for Structures	Cubic Metre

2.6 EMBANKMENT

2.6.1 Description

This work shall consist of the construction of embankment and fill by furnishing, placing, compacting and shaping suitable material of acceptable quality obtained from approved sources in accordance with these Specifications and to the lines, levels, grades, dimensions and cross sections shown on the Drawings or as required by the Engineer.

2.6.2 Materials

All fill materials shall be free from roots, sods or other deleterious material.

Materials for embankments shall be from sources which the Contractor shall propose and which shall be approved by the Engineer. Approval shall normally be given to the use of material which, when compacted to 95% of maximum dry density determined in accordance with STP 4.4 has a 4 day soaked CBR value of not less than 6%.

- Liquid limit of soil fraction passing 0.425 mm sieve not to exceed 40% (STP 3.2)
- Plasticity index of soil fraction passing 0.425 mm sieve not to exceed 10 (STP3.2) and passing 75µm not to exceed 35% (STP 3.3)

Test and other properties shall meet the requirement as per section 2.8.

2.6.3 Construction Methods

2.6.3. a Preparation of Foundations for Embankment

Prior to placing any embankment upon any area, all clearing and grubbing operations shall have been completed in accordance with Section 2.1 and excavation under carriageways shall be carried out in accordance with Section 2.2.

The original ground surface shall be disturbed as little as possible except for levelling of dikes, terraces and obsolete ditches.

Existing ditches etc., shall be closed at the embankment as described in Section 2.1.3.d. Embankments in swamps or water shall be constructed as indicated on the Drawings and as described in these Specifications. The Contractor shall, when ordered by the Engineer, excavate or displace swamp ground (Section 2.2.3) and backfill with river or beach sand unless otherwise directed by the Engineer.

2.6.3.b Placing Embankment

A) General

Except as otherwise required by the Drawings, all embankments shall be constructed in layers approximately parallel to the finished grade of the roadbed. During

construction of embankment, a smooth grade having an adequate crown shall be maintained at all times to provide drainage.

The placing of fill shall be carried out in successive layers for the full width of fill as shown on the Drawings with allowance being made for the placement of topsoil if applicable and in such lengths as are suited to the watering and compaction methods utilised. Each layer shall not exceed 150 mm in thickness on completion of compaction. This could be intentional for site-specific conditions (e.g., using heavier compaction equipment), but this requires verification through a trial bed to ensure compliance with project requirements and to mitigate risks of under-compaction. The completed embankment shall have the required form, cross-section, grade and levels as detailed on the drawings or as directed by the Engineer with a surface tolerance of $\pm 25\text{mm}$ from the specified levels.

Embankment fill placed adjacent to structures shall be in accordance with Section 2.5.3.6.

B) Placing Embankment over Swampy Ground

Where new embankment will overlay existing canals, ditches, ponds or other waterways, these shall be filled in exclusively with sand in accordance with Section 2.4.3.3. Prior to filling, cofferdams shall be made to allow pumping, and the bed shall be left to dry until approved by the Engineer for filling.

The Works shall be performed in such a manner and at such times as to avoid interruption of or interference with the free flow of water in the canals.

Full compensation for conforming to these requirements shall be considered included in other rates within the Contract items, and no additional payment will be made.

C) Widening of Existing Embankment

Where embankment fill is being carried out to widen an existing embankment the new fill material shall be fully keyed into the old embankment by means of benching which shall be in steps each not less than 300 mm high and 600 mm wide. Steps shall be cut in advance of the filling. Material cut in benches may be used as fill if found to be suitable.

2.6.3.c Compaction of Embankment.

The Contractor can conduct field trial using the same embankment material with variable moisture content to determine the moisture content needed to achieve the desired density, otherwise the moisture content should not be more than the Optimum Moisture Content. The achieved dry density of the embankment after compaction

shall not be less than 98% of maximum dry density determined earlier in accordance with AASHTO T 180. Static Deformation Modulus E_{v2} shall be 60 MPa and E_{v2}/E_{v1} shall be ≤ 2.5 (Technical Standards including ASTM 1195/ASTM 1196 and DIN 18134). Testing for E_{v2} and E_{v1} is mandatory; however, it is important to note that the test results will not be used as acceptance criteria but solely for record keeping purpose.

Dredged sand should be stockpiled outside and not be brought to the roadway. One density test for each 1,000 square metres of a completed layer will be carried out according to STP 6.2, unless otherwise directed by the Engineer. If test results show that the density is less than the required density, the Contractor shall carry out further compaction to obtain at least the required density. The compacted layer shall be approved by the Engineer before the Contractor can commence a new layer.

In addition to the density test, one Dynamic Cone Penetrometer (DCP) test shall be carried out for each 500 sqm of a completed layer; the rate of penetration from the test should not exceed 38 mm/ blow.

When necessary, each layer, before being compacted, shall be mixed with dry material or otherwise processed to bring the moisture content sufficiently close to optimum to make possible its compaction to the required density. The material shall be so worked as to have a uniform moisture content through the entire layer.

Each layer of material shall be compacted uniformly by use of adequate and appropriate compaction equipment. The compaction shall be done in a longitudinal direction along the embankment and shall generally begin at the outer edges and progress toward the centre in such a manner that each section receives equal compactive effort.

Hauling equipment shall be operated over the full width of each layer in so far as practicable.

2.6.4

Measurement

Embankment shall be measured in cubic metres based on cross sections of accepted embankment constructed and completed in accordance with the Specifications, to the lines, levels and grades required or as directed by the Engineer.

The cross section to be used will be the area bound by the subgrade (below improved subgrade or sub-base) the side slopes or edge limits and the original ground line or the level after excavation of unsuitable material with the net volume being calculated by the End area method. A deduction of volume will occur when topsoil is placed in accordance with Section 6.6 of this Specification.

No allowance will be made for material cut in benching operations.

The final volume of embankment fill shall not include the voids for bridges and box-culverts, but the voids for pipes, manholes, catch basins and the like will however not be deducted.

Sand backfill to swampy ground shall be measured in cubic metres based on the net volumes backfilled as directed by the Engineer.

2.6.5 **Payment**

This work measured as provided above shall be paid for at the Contract unit prices per cubic metre. Payment shall be full compensation for performing the work, furnishing the materials and providing all labour, equipment, tools and incidentals necessary to complete the work.

Partial payment may be made on measured volumes of required embankment fill actually executed. The Engineer will set terms for deduction in this quantity to compensate for work not fully completed.

Pay items shall be:

2/6/1	Embankment Fill from Excavation on Site	Cubic Metre
2/6/2	Embankment Fill from Borrow Pit in Contractor's Arranged Land	Cubic Metre
2/6/3	Embankment fill by dredged sand	Cubic Metre
2/6/4	Sand Backfill to Swamp for construction platform	Cubic Metre

2.6.6 **Cladding Material**

2.6.6.a **Description**

Cladding material use as a part of dredged sand embankments shall be clayey silt with a plasticity index as determine in accordance with AASHTO T90, of 10 to 20 per cent and free from all sorts debris, organic materials .

Embankments shall be protected from scour and erosion by a layer of cladding material as specified in the finished thickness shown on the engineering drawings giving a layer width of 0.9m to 1.2 m as per direction of engineer. This material shall be spread in layers not exceeding 200mm loose thickness and compacted by means of suitable size equipment to a density of 95 per cent of the maximum dry density as determined by AASHTO T180 and 4 days soaked CBR Value of not less than 4%. Construction of cladding layer will be integrated with embankment/pavement construction and follow the procedure describe in relevant section of 2.6. No part shall be left for partly construction after embankment construction. Care shall be taken

to ensure that the drainage paths of trench drains do not blocked due to cladding construction.

2.6.6.b Measurement

Cladding material shall be measured in cubic meters. The quantity of cladding material shall be required cladding soil of the designated thickness complete and accepted by the engineer in charge. When the earthworks do not conform to the required dimension and side slopes of embankments or excavation requiring cladding soil are of greater area than required, the area measured shall be there required area as if the earthwork had conformed to the required dimension.

2.6.6.c Payment

This work measured as provided above, shall be paid for at the Contract unit price per cubic metre. The price shall be full compensation for furnishing, placing and compacting all material, including all materials cost and labour, equipment, tools and incidentals necessary to complete the work.

No payment will be made for cladding soil until it has been grassed.

Pay items shall be:

2/6/5 Cladding Soil - Cubic Meter

2.6.7 Vetiver (Binna Grass/Lawn Grass) Application

2.6.7.a Description

Vetiver grass (Binna Grass) is an effective, low-cost, and sustainable solution for protecting coastal and river embankments from damage caused by storm surges, floods, and other natural hazards by increasing soil shear strength and reducing erosion from rain and storm surges. Its dense, deep root system creates a strong, stable soil matrix that resists displacement, while the above-ground growth intercepts raindrops and reduces surface runoff. This bio-engineering technique provides environmental benefits, is adaptable to various soil and climatic conditions, and is significantly more affordable than traditional structural methods.

2.6.7.b Measurement

Binna Grass shall be measured in square meters. The quantity of Binna Grass shall be required counting the stems in a bunch and plated at a specified gap center to center all over the side slope of embankment beyond the edge of the shoulder which shall be accepted by the engineer in charge. After planting the Binna Grass, watering the Grass till the Grasses are fully grown shall be completed as per direction of Engineer In Charge. The Stem should be 125mm to 150mm long with roots. The payment is to be made only when Binna Grasses are fully grown to the required dimension.

2.6.7.c Payment

This work measured as provided above, shall be paid for at the Contract unit price per square metre on the condition of when Binna Grasses are fully grown to the required dimension. The price shall be full compensation for furnishing, placing/planting and watering of the grown Grasses, including all materials cost and labour, equipment, tools and incidentals necessary to complete the work.

Pay items shall be:

2/6/6	Binna Grass	-	Square Meter



2.7 PREPARATION OF SUBGRADE

2.7.1 Description

This work shall consist of the preparation of subgrade in embankment, or in cut by removing, scarifying, watering, compacting and shaping existing or previously placed material in accordance with these Specifications and to the lines, levels, grades, dimensions and cross sections shown on the Drawings or as required by the Engineer.

2.7.2 Materials

Materials for subgrade shall be same as in Section 2.6.2 except the CBR value shall be 8.

2.7.3 Construction Methods

The subgrade shall be prepared over the full width of the embankment including shoulders. Part width working may be allowed with the prior written approval of the Engineer.

The subgrade shall be prepared in lengths of not less than 100 metres at any one time, unless otherwise approved by the Engineer.

Where the subgrade is in embankment, the subgrade layers to the required depth shall be compacted to achieve dry density not be less than **98%** of maximum dry density (MDD) determined earlier in accordance with **Modified Proctor Test** (where at top of Subgrade Static Deformation Modulus EV2 shall be 120 MPa and Ev2/Ev1 shall be ≤ 2.3 , Technical Standards including ASTM 1185/ASTM1196 and DIN 18134) **(STP 4.4)**. Testing for Ev2 and Ev1 is mandatory; however, it's important to note that the test results will not be used as acceptance criteria but solely for record keeping purpose.

In the case of road sections in cut or in case of full reconstruction of pavements, where the existing subgrade does not meet the above compaction criteria upto a depth of 300 mm, the material in the upper layer will be first removed and stacked separately. The bottom layer shall be scarified until the soil is fully loosened; any lumps or clods shall be removed or broken to pass 50 mm sieve. The layer shall be compacted to achieve the minimum compaction level as given above, and minimum **CBR of 8%**. Any unsuitable material occurring within the layers shall be removed and replaced by approved materials. The second layer of subgrade shall be laid after testing and approval the first layer and compacted to similar specifications.

The achieved dry density after compaction of the subgrade layer shall not be less than 98% of maximum dry density as determined in accordance with STP 4.4.

The material shall be worked as to have a uniform moisture content through the entire layer.

The subgrade material shall be compacted uniformly by use of adequate and appropriate compaction equipment. The compaction shall be done in a longitudinal direction along the embankment and shall generally begin at the outer edges and progress toward the centre in such a manner that each section receives equal compactive effort.

Samples to determine the compaction shall be taken regularly with a set of three samples for each 1,000 square metres of finished layer or as decided by the Engineer will be carried out according to STP 6.2. If the test results show that the density is less than the required dry density, the Contractor shall carry out further compaction to obtain at least the required dry density. The compacted subgrade layer shall be approved by the Engineer before the Contractor can commence a new layer.

The surface of the finished subgrade shall be neat and workmanlike and have the required form, super elevation, levels, grades and cross section. The finished surface shall be constructed with a tolerance of 20 mm above or below the specified levels at any point.

2.7.4 Measurement

Subgrade preparation shall be measured in square metres based on the surface area of compacted and accepted subgrade actually completed in accordance with the Specifications, to the lines, levels, grades and cross sections required as directed by the Engineer. No allowance will be made for overlapping of areas due to half width working.

No differentiation will be made between subgrade compaction in cut or in fill.

2.7.5 Payment

This work measured as provided above shall be paid for at the Contract unit prices per square metre. Payment shall be full compensation for performing the work and providing all labour, equipment, tools and incidentals necessary to complete the work.

The rates shall not include the cost of furnishing the subgrade materials which, if not existing, shall be included in the quantity for fill material as provided for in Section 2.6.

Pay item shall be:

2/7/1	Preparation of subgrade 300 mm Depth	Square Metre
2/7/2	Preparation of subgrade 450 mm Depth Metre	Square Metre

2.8 IMPROVED SUBGRADE

2.8.1 Description

This work shall consist of furnishing, placing and compacting improved subgrade material on a prepared and accepted subgrade in accordance with these Specifications,

and to the lines, levels, grades, dimensions and cross sections shown on the Drawings, or as required by the Engineer.

2.8.2 Materials

Material shall be a natural or artificial mixture of sand or other mineral aggregates, free from vegetable matter, soft particles, clay and excess quantities of silt.

Plasticity. The portion of material passing the 0.425 mm sieve shall not to exceed 6, when tested in accordance with test procedure STP 3.2.”

CBR. The material shall have a soaked CBR value not less than 12, when compacted to 95% of maximum dry density as determined by STP 4.4 (Modified compaction).

Suitable (Passing 75 μ m not to exceed 35%) measures shall be taken for protecting the material from erosion

2.8.3 Construction Methods

2.8.3.a Preparation of Subgrade

Notwithstanding any earlier approval of subgrade, any damage to or deterioration of subgrade shall be made good before the improved subgrade is laid.

Preparation of the subgrade shall be carried out, unless otherwise agreed by the Engineer, immediately prior to laying the improved subgrade.

2.8.3.b Spreading

Improved subgrade shall be spread in layers, with uncompacted thickness up to 200 mm, subject to the approval of the Engineer, and the layers shall be as nearly equal in thickness as possible.

Where the material for shoulders is the same as that used for the improved subgrade course, the material shall be placed for the full width of the roadbed and the shoulders simultaneously.

Where the shoulders are not of the same material as the improved subgrade course, then the improved subgrade shall be spread to give the required compacted depth and the edge detail shown on the Drawings.

When the improved subgrade course is spread contiguous to concrete kerbs or gutters, extreme care shall be exercised not to damage the kerbs or gutters. Any damage of kerbs or gutters resulting from carelessness or negligent construction methods by the Contractor shall warrant the removal and replacement of said kerbs or gutters at the Contractor's sole expense.

2.8.3.c Sprinkling, Rolling and Compacting

Each layer shall be compacted to at least 95% of the maximum dry density as determined by AASHTO T180. At top of Improved Subgrade Static Deformation Modulus EV2 shall be 120 MPa and $Ev2/Ev1$ shall be ≤ 2.3 , Technical Standards including ASTM 1195/ASTM 1196 and DIN 18134. Testing for $Ev2$ and $Ev1$ is mandatory; however, it's important to note that the test results will not be used as acceptance criteria but solely for record keeping purpose. Three in situ density tests in accordance with STP 6.2 shall be taken from each 1,000 square metres of compacted improved subgrade, or as directed by the Engineer. If the achieved density is less than the minimum required, the Contractor shall carry out further compaction. Nuclear Density test can be used with proper calibration.

When commencing work on the improved subgrade the Contractor shall carry out a field compaction trial to determine the optimum moisture content and the required number of passes of his particular compaction equipment to comply with the Specification. This method will be approved by the Engineer and shall be used for all subsequent compaction of improved subgrade material. Such agreement will not however relieve the Contractor of his responsibility and in the event that test results later show that the specified compaction is not being achieved all improved subgrade work shall cease and not be resumed until a fresh trial has been undertaken and a revised compaction method approved by the Engineer.

In order to ensure uniform bearing capacity at the finished improved subgrade level, CBR tests shall be carried out as directed by the Engineer. The CBR shall be such that the laboratory value obtained in accordance with STP 5.1, at the specified compaction and after 4 days soaking, shall exceed 12. In areas where these requirements are not met, correction shall be made by such measures as the Engineer deems necessary.

Immediately after each layer has been spread and shaped satisfactorily, each layer shall be thoroughly compacted with suitable and adequate compaction equipment approved by the Engineer. Rolling operations shall begin from the outer edge of roadbed toward the centre, gradually in a longitudinal direction; except on super-elevated curves, where rolling shall begin at the low side and progress towards the high side.

Improved subgrade material which does not contain sufficient moisture to be compacted in accordance with the requirements of this Section shall be watered by methods approved by the Engineer at the Contractor's own expense. Improved subgrade material containing excess moisture shall be dried prior to or during compaction by methods approved by the Engineer, at the expense of the Contractor.

The finished improved subgrade shall follow the required grades and cross sections and at any point shall not vary more than 20 mm above or below the specified level. The thickness of the finished improved subgrade shall be:

-not thinner than 20 mm less than the required thickness at any point

-overall not less than the required thickness when five thickness measurements are averaged in any 100 metres of road.

Improved subgrade which does not conform to the above requirements shall be reworked, watered and thoroughly re-compacted to conform.

2.8.4 **Measurement**

Improved subgrade as described in this section shall be measured by the cubic metres of material compacted in place and accepted. Measurement shall be based on the average width and thickness of the improved subgrade shown on the Drawings and actual length measured horizontally along the centreline of the surface of the road.

2.8.5 **Payment**

This work measured as provided above shall be paid for at the Contract unit rate per cubic metre for improved subgrade. The payment shall be full compensation for furnishing all materials, hauling, placing, compacting, sprinkling, finishing and shaping, and for all labour, equipment, tools and other incidentals necessary to complete the work specified.

Pay item shall be:

2/8/1	Improved Subgrade	Cubic Metre

2.9 REMOVAL OF EXISTING STRUCTURES

2.9.1 Description

This work shall consist of the satisfactory removal and salvage or disposal, wholly or in part, of existing bridges, structures, substructures, buildings, culverts etc., within the right-of-way as indicated in the Contract Documents or as required by the Engineer.

The Employer will generally arrange for all structures within the right-of-way, which are not the property of the Employer to be removed by the respective owners prior to the Contractor commencing work on site.

Existing structures which are the property of the Employer and which are in the vicinity of a proposed roadway shall be dismantled or demolished by the Contractor to a level one metre lower than the proposed road surface elevation. For areas of the Site that will be used for purposes other than roadways, existing structures shall be dismantled or demolished to a level lower than the lowest elevation of the finished ground level, as indicated on the Drawings or directed by the Engineer.

2.9.2 Materials Obtained from Dismantling

The materials in the existing structures may include but are not restricted to structural steel, reinforced concrete materials, or stone/brick masonry materials, in any combination. The concrete materials, stone/brick masonry materials obtainable from dismantling of structure shall be taken to stock-piles by the Contractor for their possible use in the works when so approved by the Engineer.

The materials salvaged from dismantling may not in itself comply fully with specifications for intended use in the permanent works. The salvaged material shall be first sorted out as directed. The materials, which may be used directly in permanent works, shall be stockpiled separately from those that require processing for reuse. The materials selected for processing should be of such quality as will meet the specifications after breaking, screening and / or mixing with better quality materials if necessary.

Acceptability of the materials (after processing as the case may be) shall be determined by the Engineer and only such materials that fully satisfy the specifications in all respects shall be permitted for incorporation in the permanent works.

Structural/reinforcing steel obtained from dismantling of the existing structures is not considered suitable for use in the permanent works. This will be the property of the Contractor; it will not be reused for the permanent Works, and shifted/disposed of from the site with intimation to the Engineer. Structures or portions thereof which are specified in the contract for re-erection shall be stored in separate piles in a location agreed by the Engineer.

The Contractor shall comply with all laws, ordinances, building regulations etc. as prevailing in Bangladesh.

2.9.3 **Backfilling after Dismantling of Structures**

As directed by the Engineer, holes and depressions caused by dismantling operations shall be backfilled with excavated or other approved materials and thoroughly compacted in line with surrounding areas. The backfilling required for restoring the ground after dismantling of structures shall not be paid separately as the cost shall be included in the rate for dismantling structures.

2.9.4 **Measurement**

The dismantling or rehabilitation, disposal of the material and the backfilling after dismantling of structures shall be measured as a Lump Sum per structure.

2.9.5 **Payment**

The Lump Sum (LS) amounts rates for the various items of dismantling or rehabilitation shall be the full compensation for carrying out the required operations including excavation backfilling and shaping and providing all labour, materials, tools, equipment, safeguards and incidentals necessary to complete the work for each individual structure. These will also include for handling, sorting out, salvaging, and stock piling usable materials.

All materials from existing structures, which are suitable for use in the road pavement, shall be stockpiled in a manner approved by the Engineer. The rate per cubic metre inserted by the Contractor against pay item 2/9/3 shall be deducted from payments due to the Contractor.

Pay item shall be:

2/9/1	Dismantling existing structure (Box Culvert/Pipe Culvert/Bridge) including disposal of spoil and backfilling (Individual Structure to be stated in Bill of Quantities).	Lump Sum
2/9/2	Dismantling portions of existing structure including Stockpiling of materials (Individual Structure to be stated in Bill of Quantities)	Lump Sum
2/9/3(a)	Deduction of the Value of Recovered Materials (Except Reinforcing steel) from Structures	Cubic Metre
2/9/3(b)	Deduction of the Value of Recovered Materials (reinforcing Steel) from Structures	Tonnes

2.10 CONSTRUCTION OF EARTHEN SHOULDERS

2.10.1 Description

This work shall consist of the construction of shoulders to the road pavement by furnishing, placing, compacting and shaping suitable material of acceptable quality obtained from approved sources in accordance with these Specifications and to the lines, levels, grades, dimensions and cross sections shown on the Drawings or as required by the Engineer.

2.10.2 Materials

All shoulder materials shall be free from roots, sods or other deleterious material.

Materials for shoulders shall be from sources, which the Contractor shall propose and which shall be approved by the Engineer. Approval shall not normally be given to the use of material from borrow areas which, when compacted to 98% of maximum dry density in accordance with STP 4.3, has a 4 day soaked CBR value of less than 8%. Shoulder materials shall conform to the following requirements.

- Liquid limit of soil fraction passing 0.425 mm sieve not to exceed 40% (STP 3.2)
- Plasticity index of soil fraction passing 0.425 mm sieve to be greater than 11 (STP 3.2)

2.10.3 Construction Methods

2.10.3.a Preparation

Prior to placing any shoulder fill, all subgrade preparation and subgrade drainage work shall be complete.

2.10.3.b Placing

Except as otherwise required by the Drawings, all shoulders shall be constructed in layers approximately parallel to the finished grade of the roadbed. The layers shall not exceed 150 mm in thickness on completion of compaction.

Attention is drawn to the requirements for shoulders to be constructed in stages with the road pavement layers. The finished surface of the soft shoulder shall have a tolerance of ± 20 mm from the specified level for the full width, except that where it adjoins a hard shoulder then the level at this point must be equal or lower than the finished level of the approved hard shoulder.

2.10.3.c Compaction of Shoulders

The achieved dry density after compaction shall not be less than 98% of the maximum dry density as determined in accordance with STP 4.3.

Samples to determine the compaction shall be taken regularly, with one sample for each 500 square metres of finished layer, or as directed by the Engineer. Such density tests will be carried out according to STP 6.2. If test results show that the achieved dry density is less than the minimum required, the Contractor shall carry out further compaction. Each compacted layer shall be approved by the Engineer before the Contractor can commence a new layer.

2.10.4 **Measurement**

Shoulders shall be measured in cubic metres based on cross sections compacted and accepted in place. The volume to be measured will be the net volume of required and accepted shoulder, constructed and completed in accordance with the Specifications, to the lines, levels, grades and cross sections required or as directed by the Engineer.

2.10.5 **Payment**

This work measured as provided above shall be paid for at the Contract unit prices per cubic metre. Payment shall be full compensation for performing the work, furnishing the materials and providing all labour, equipment, tools and incidentals necessary to complete the work.

Pay item shall be:

2/10/1	Construction of Soil Earthen Shoulders	Cubic Metre

2.11 CONSTRUCTION OF HARD SHOULDERS

2.11.1 Description

This work shall consist of the construction of hard shoulders to the road pavement by furnishing, placing, compacting and shaping suitable material of acceptable quality obtained from approved sources in accordance with these Specifications and to the lines, levels, grades, dimensions and cross sections shown on the Drawings or as required by the Engineer.

2.11.2 Materials

The materials for hard shoulder shall meet the requirements for aggregate base type II provided for in Section 3.3.2

2.11.3 Construction Methods

2.11.3.a Preparation of Sub-base

The sub-base shall be shaped and compacted in conformity with the provisions of Section 3.2 to the correct moisture content, and be completed for at least 100 metres ahead of the placing of the hard shoulder material, unless otherwise approved by the Engineer.

2.11.3.b Spreading Hard Shoulder

The aggregate and sand shall be mixed thoroughly to obtain a homogenous mix complying with either grading A or B of Section 3.3.2. Water shall be added during mixing to keep the mixed material moist so as to prevent segregation during transportation.

The mixed hard shoulder material, which should be at or near optimum moisture content shall be spread in two layers of nearly equal thickness so that the compacted thickness shall conform to that shown on the Drawings or as directed by the Engineer. All areas of segregation shall be corrected, or removed and replaced with well graded material.

Where the material for hard shoulders is the same as that used for the base course, the material shall be evenly spread in layers, as herein specified, for the full width of the roadbed and the base course and the shoulders should be constructed simultaneously.

At the edge of the hard shoulders the hard shoulder material shall be spread to give the required compacted depth and the edge detail shown on the Drawings.

2.11.3.c Sprinkling, Rolling and Compacting

Immediately after each layer has been spread and shaped satisfactorily, each layer shall be thoroughly compacted with suitable and adequate compaction equipment approved by the Engineer.

Hard shoulder material, which does not contain sufficient moisture to be compacted in accordance with the requirements of this Section, shall be sprinkled with water. The Contractor shall supply the necessary water at his own expense.

Hard shoulder material containing excess moisture shall be dried prior to or during compaction. Drying of wet material shall be performed by methods approved by the Engineer, at the expense of the Contractor.

Each layer shall be compacted to at least 98% of the maximum dry density as determined by STP 4.5 (Vibrating Hammer). Density of the compacted hard shoulder shall be determined in accordance with STP 6.2 (150 mm or 200 mm diameter), with at least one test being made for each 200 linear metres of hard shoulder.

The final shaping and rolling of the soft shoulder to the full width shall be made after the hard shoulder is completed.

2.11.3.d Surface Tolerance

The finished surface of the hard shoulder shall follow the required grades, levels and cross-sections and shall not vary from the specified level by more than $\pm 10\text{mm}$. The finished surface shall also not deviate by more than 10mm from a 3m long straight edge laid perpendicular and parallel to the road centre-line. Any areas having irregularities greater than 10 mm, shall be corrected by loosening, adding or removing material, reshaping and re-compacting.

The minimum thickness at any single point shall be not less than the required thickness less 10 mm. The hard shoulder shall also have an average thickness not less than the required thickness when five thickness measurements are averaged in any 100m length of completed shoulder.

The Contractor shall carry out at his own expense, the reconstruction of areas of hard shoulder, which are too thin or too variable in thickness to meet this requirement.

2.11.4 Measurement

This item shall be measured as the number of cubic metres of material complete in place and accepted. Measurements shall be based on the cross section of the hard shoulder shown on the Drawings and the actual length measured on the surface of the road.

2.11.5 Payment

This work measured as provided above shall be paid for at the Contract unit rates per cubic metre for hard shoulder. The payment shall be full compensation for furnishing all materials, hauling, placing, compacting, sprinkling, finishing and shaping and for all labour, equipment, tools and other incidentals necessary to complete the work.

Hard shoulder shall be paid for at the Contract unit rates irrespective of the sources of material used. All costs of excavating existing pavement or savings to the Contractor from re-using materials excavated from existing pavements in section 2.2 should be included under this item.

Pay items shall be:

2/11/1	Construction of Hard Shoulder	Cubic Metre



2.12 SUBGRADE DRAINS

2.12.1 Description

This work shall consist of excavating, furnishing material, backfilling and finishing drains to the prepared and accepted subgrade in accordance with these specifications and the dimensions and cross sections shown on the drawings, or as required by the Engineer.

2.12.2 Materials

The material for backfilling of subgrade drains shall be clean free draining sand and gravel, free from any vegetable matter, soft particles, silt or clay.

The grading requirement of the drain backfill material shall conform to that shown in Table 2.12-1 below:

Table 2.12-1

Sieve size	% passing by weight Min – Max
10 mm	100
5 mm	80-100
2.4 mm	65-95
1.2 mm	50-80
0.6 mm	25-50
0.3 mm	10-20
0.15 mm	0-10
0.075 mm	0-2

The separator material shall consist of suitable approved geotextile membrane. The separator shall be of adequate strength to protect the drainage material from contamination during construction of the pavement and shoulder and shall allow the free passage of water whilst preventing the contamination of drainage backfilling material with fine soil particles. Samples of proposed materials shall be submitted by the contractor not less than one month prior to commencement of drainage works. The Engineer shall order the contractor to carry out tests and field trials necessary to ensure the adequacy of the material prior to approval. Geo-textile filter fabric used in the works shall conform to the relevant sub-section of 2.14.

2.12.3 Construction Methods

Subgrade drains shall be excavated neatly by hand in the prepared subgrade to dimensions and grades and intervals shown on the drawings or directed by the Engineer. Drains on opposite sides of the road shall be staggered.

The excavation shall be backfilled with material in accordance with Table 2.12-1. The backfill shall be compacted by hand ramming and struck off level with, or slightly above, the finished subgrade level.

The finished backfill shall be immediately covered with approved separator material, which shall extend 150 mm beyond the edges of the drain on all exposed faces. Any joints in the fabric shall be overlapped by at least 150 mm. Fabric shall be held in place by suitable means to prevent movement of the separator during construction operations.

Shoulder and pavement materials over the drain and separator shall be carefully placed by hand for a depth of not less than 100 mm prior to placing and rolling of the general shoulder pavement materials.

2.12.4 **Measurement**

Subgrade drains shall be measured in linear metres of drain completed and accepted.

Drains shall extend from a point vertically below the outer edge of the carriageway, or paved shoulder, to the finished face of the embankment, or side ditch. In the event that the contractor constructs the embankment to dimensions in excess as those shown on the plans and sections additional length of subgrade drains shall be at the Contractor's expense.

2.12.5 **Payment**

The work measured as provided above shall be paid at the contract unit rate per linear metre. Payment shall be full compensation for performing the work and providing all labour, equipment, materials, tools and incidentals necessary to complete the works.

Pay item shall be:

2/12/1	Subgrade drains (300mm x 500mm)	Linear Metre

2.13 **GROUND IMPROVEMENT FOR WEAK EMBANKMENT FOUNDATION**

2.13.1 **Scope**

The scope for improving the ground of problematic sub-soil conditions comprises of several alternatives and combination of more than one of the following alternatives.

The improvement may be chosen based on the sub-soil conditions:

1. Using geosynthetic drains (Prefabricated Vertical Drain (PVD) with surcharge to achieve 90% consolidation of sub-soil within a prescribed time.
2. Stone/Sand columns.
3. Sand drain.
4. Using High-Strength Soil Reinforcement Geosynthetics as a load-bearing platform.

2.13.2 PRE-FABRICATED VERTICAL DRAIN (PVD)

2.13.2.1 Description

This Specification covers the requirements for the supply and installation of prefabricated vertical drains (PVD) plus the associated works for the purpose of achieving the desired degree of consolidation settlement at specified locations.

The Contractor shall provide all necessary resources including skilled labor, proper machine/tools, and materials to complete all the scope of works for the installation of PVD in accordance with the approved method statement, shop drawings, and this specification. Any alternate methods proposed by the contractor shall be at the discretion of Engineer and will have to be prior approved before commencement of work.

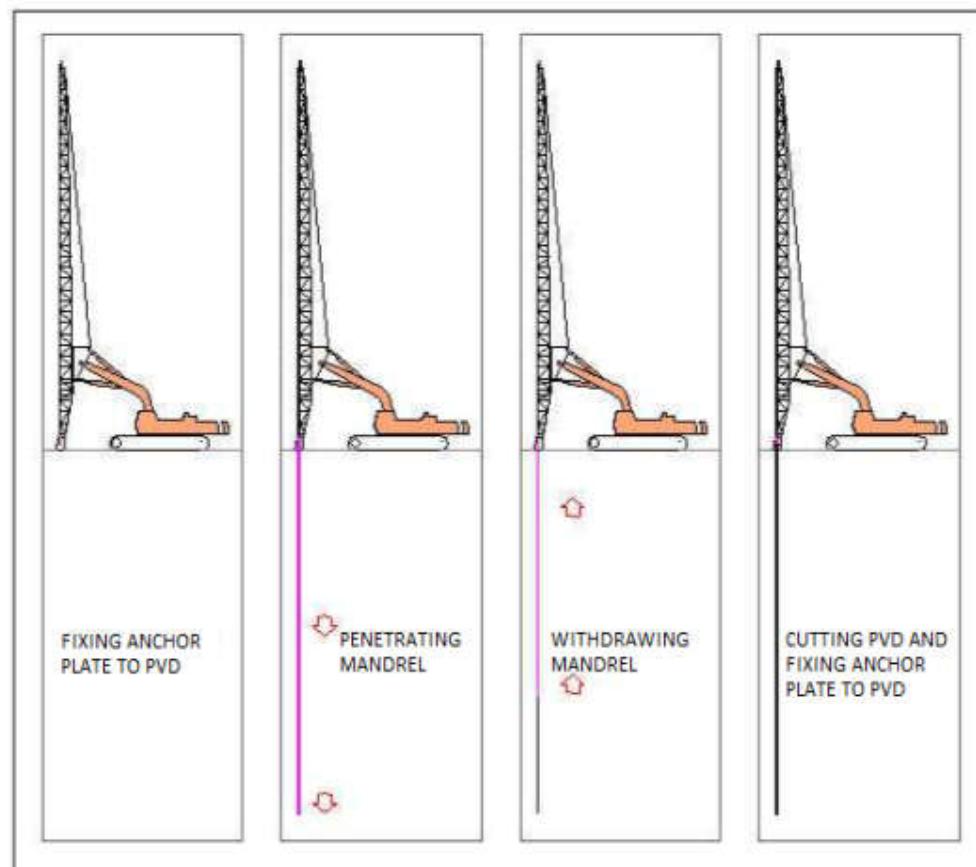


Figure 13-1. PVD installation process

2.13.3.1 Materials

The material and equipment used for testing shall be prior approved by the Engineer

- i) Geosynthetic Drain: Geosynthetic strip or band drain shall be manufactured by an ISO 9001 or equivalent certified manufacturer. It shall consist of a corrugated or studded or 3D mesh consisting of an inner core of thick polyester fused at intersection, wrapped

in a non-woven geotextile. Band drain shall be of width and thickness as specified in the design and shall be a minimum of 100 mm width and 4mm thickness. The core shall serve as the drainage medium conveying the core water from the soft subsoil to the drainage layer at the top. The core shall be of three dimensional meshes made of polyester or equivalent. The filter should be non-woven needle punched adhesive-bonded fabric. The filter and the core shall be ultrasonically welded together at the edges to produce a fully integrated product. The drain shall conform to the properties specified in the table below:

Table 13-2. Geometric properties of drain

Property		Test Designation	Specified Requirements
Dimension of PVD Drain	Width	-	100 ± 5 mm
	Thickness	ASTM D5199	≥4 mm

Table 13-3. Physical and Hydraulic Properties of Drain

Property	Test Method	Proposed Values	Remarks
Tensile Strength (full width of PVD)	ASTM D4595 or equivalent	>2.5 kN	
Elongation at 1.0 kN (full width of PVD)	ASTM D4595 or equivalent	≤ 10%	
Discharge capacity of new straight PVD at 250 kPa & hydraulic gradients of 1	ASTM D4716 or equivalent	≥ 500m ³ /year	
Tensile strength of filter jacket*	ASTM D4595 or equivalent	>3 kN/m	
Apparent opening size of filter jacket (O95)	ASTM D4751 or equivalent	< 75 um	
Puncture Resistance	ASTM D 4833 or equivalent	> 0.1 KN	
Coefficient of permeability of filter jacket	ASTM D4491 or equivalent	>1x10 ⁻⁴ m/s	
O95/D15 (Opening Size of Filter/Grain Size of Clay)		≥ 3	
O50/D50 (Opening Size of Filter/Grain Size of Clay)		< 24	

*For installations deeper than 25 m or in difficult soil conditions, a minimum tensile strength of 6 kN/m in the longitudinal direction for filter jacket may be adopted. (BS EN 15237:2007 or equivalent).

Test results (ASTM D4595) or equivalent on spliced/joined PVD by independent ISO/IEC 17025 accredited laboratory shall be included, if relevant.

Engineer reserves the right to take any additional individual samples at any time for tests by independent ISO 17025 accredited laboratory whenever the PVD is suspected to be defective.

The drains shall be installed to depths and at spacing as per the design and drawings. The Contractor shall submit to the Engineer the complete scheme for the installation of vertical band drains along with the particulars and test results from the manufacturer showing conformance to the specifications. Unless specified otherwise, the design of the ground improvement measures shall be to achieve 90 percent consolidation in the time prescribed by the employer. The equipment and the methodology for installation of the drains shall satisfy the specified requirement of the prescribed degree of consolidation and the time for achieving the same.

- ii) Granular Sand Blanket: After installation of the vertical band drains in the sub-soil, a blanket of well-draining granular material/coarse sand (natural or crushed) conforming to grading given in below table of specified thickness compacted to a density of 75 to 80 percent of maximum dry density obtained by heavy compaction shall be provided. The granular sand blanket shall be exposed to atmosphere at its periphery for dissipation of pore water pressure.

Table 13-4. Gradation of Granular Sand Blanket

Sieve Designation	Percent Passing by Weight (Min-Max)		
	Type A	Type B	Type C
63 mm	100	-	100
37.5 mm	100	100	85-100
25.00 mm	100	-	-
19 mm	100	-	0-20
9.5 mm	100	45-100	0-5
4.75 mm	85-100	-	-
3.35 mm	-	25-80	-
2.00 mm	50-100	-	-
0.850 mm	25-90	-	-
0.600 mm	-	8-45	-
0.425 mm	10-75	-	-
0.300 mm	0-65	-	-
0.150 mm	0-35	0-10	-
0.75 mm	0-3.0	0-5	-

- iii) Geotextile Fabric for Separation and Drainage: The requirements of synthetic geotextile shall conform to the requirement in geosynthetic section.
- iv) Alternatively, after installation of the vertical band drains in the sub-soil, multilinear geo-composite drainage can be used above the PVD to drain out the flow of drainage water effectively to the lateral trenches or collectors. This will replace the granular sand blanket (Item ii) and geotextile fabric (Item iii). The multilinear geo-composite is a separation, drainage and filtration geo-composite which consists of the mechanical bonding of the following elements:
- A needle-punched non-woven polypropylene geotextile layer (top filter).
 - A needle-punched non-woven polypropylene capillary draining layer.
 - Polypropylene mini pipes, regularly perforated according to a 90° dual alternated axis.
 - A needle-punched non-woven polypropylene geotextile layer (bottom filter).

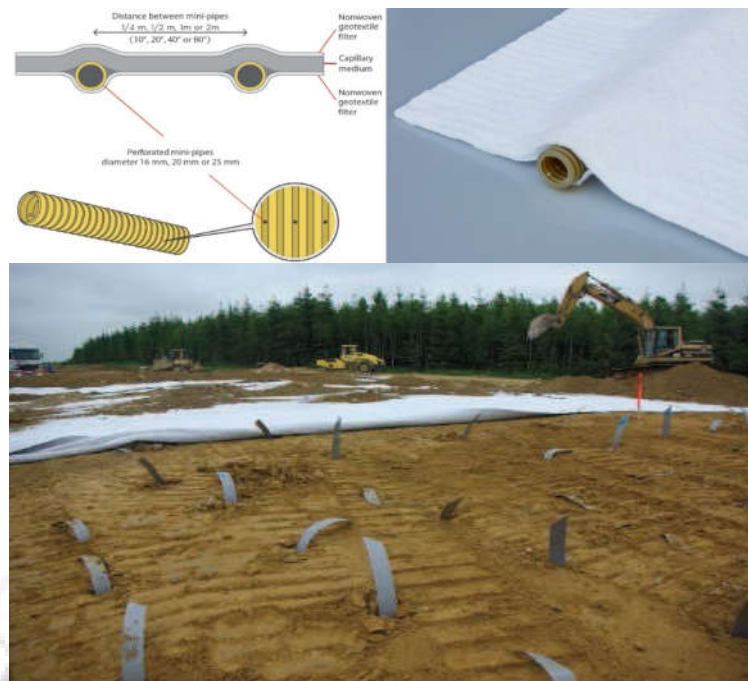


Figure 13-2. Multilinear geo-composite drain installation above PVD

Table 13-5: Mechanical and Hydraulic Properties of Multilinear Geo-composite Drain

Characteristics	Value	Standards	Reference	MARV*	Unit
Mechanical Characteristics					
Mass per unit area		EN ISO 9864	Geo-composite	485	g/sqm
			Geo-composite without mini-pipes	370	
Thickness		EN 9863 -1	Under 2 kPa	4.0	mm
			Under 20 kPa	3.2	
Tensile strength		EN ISO 10319	Machine direction	14	kN/m
			Cross direction	14	
Tensile elongation		EN ISO 10319	Machine direction	60	%
			Cross direction	60	
CBR resistance		EN ISO 12236	-	2.4	kN
Mini-pipes Characteristics					
Mini-pipe Diameter		EN 61386-1	Outside diameter	19.6	mm
Pipe stiffness at 5%		ASTM D 2412	-	4000	kPa
Spacing of mini-pipes	2 mini-pipes every one meter widthways				
Hydraulic Characteristics					
Apparent Opening size		ASTM D 4751	Filter layer	<200	µm
Water permeability		EN ISO 11058	Filter layer	0.070	m/s

*MARV= Minimum Average Roll Value

2.13.3.2 Construction and Installation Requirements

The Contractor shall prepare and submit method statement for installation of PVD/vertical band drains and the associated works along with Drawings to the Engineer for prior written approval before commencement of work

i) Transportation and storage

- a. All the PVD drain materials supplied and delivered to site shall be labelled or tagged for project/sample identification and other quality control purposes. Each pallet shall be identified by the manufacturer name/logo and lot number, individual roll number, date of manufacture, manufacturer and product identification of the filter jacket and core.
- b. All PVD delivered to site shall be recorded in site diary and/or in file with delivery note/order readily for inspection by the Engineer in an approved format.
- c. All PVD shall be properly covered and protected by heavy-duty plastic sheet from sunlight, mud, dirt, dust, debris and other detrimental substances during transport and on-site storage. The Contractor shall ensure that the PVD is in good condition and properly stored in a covered area at the worksite. In the event of any damage or deterioration of the PVD, the Contractor shall be liable to replace the affected materials at his own cost.
- d. All materials which are defective or damaged during transportation, handling or storage and do not meet the minimum requirements of the PVD drain specifications shall be rejected by the Engineer. No payment of any kind shall be made on the rejected product.

ii) Drain Installation

- a) PVD shall be located, numbered and pegged out by the Contractor using a baseline and benchmark indicated by the Engineer. The Contractor shall take all reasonable precautions to preserve the pegs and is responsible for any necessary re-pegging. The installed location of the PVD shall not vary by more than 150mm from the plan locations designated on the approved shop drawings.
- b) PVD that are deviated by more than 150mm from the design plan location or are damaged or improperly installed with machine swinging up and down, will be rejected and abandoned in place.
- c) PVD shall be installed from the working surface to the depth shown on the approved shop drawings, or to such depth as directed by Engineer who may vary the depths, spacing, or the number of drains to be installed, and may revise the plan limits for this work as necessary.
- d) During PVD installation, the Contractor shall provide the Engineer with suitable means of determining the depth of the advancing drain at any given time and the length of drain installed at each location/zone by using electronic data logger.
- e) PVD shall be installed using a continuous push using static weight. Installation techniques using driving will not be permitted. Jetting techniques or pre-boring will be permitted only after receiving written approval from the Engineer.
- f) The installation shall be performed, without any damage to the PVD drain during advancement or retraction of the mandrel. In no case will alternate raising or lowering of the mandrel during advancement be permitted. Raising of the mandrel will only be permitted after completion of an installation to the required depth.

- g) The mandrel penetration rate should be between 150mm and 600mm per second.
- h) Splices or connections in PVD should be carried out in such a manner so that it ensures continuity of flow. At least 500mm of the previous roll should be overlapped with the new roll.



Figure 13-3. PVD overlapping

- i) The end of PVD shall be provided with a suitable anchor plate to ensure that the drain is securely anchored at its base providing minimum disturbance to the in-situ soil.

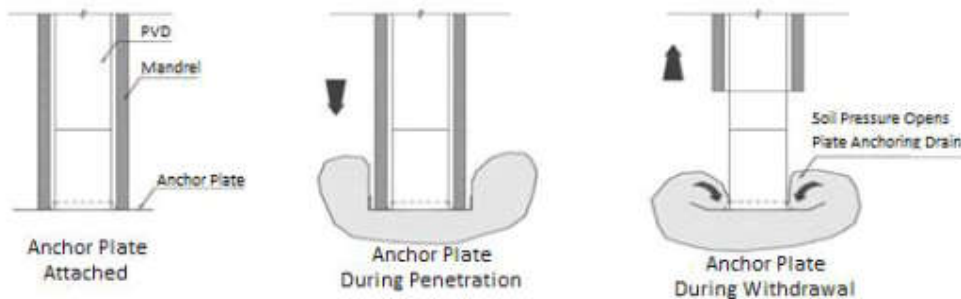


Figure 13-4. Anchor plate at the end of PVD

- j) The completed PVD shall be cut off neatly at least 300mm above the working grade, or as otherwise specified on the drawings.
- k) The Contractor may use augering, spudding, or other approved methods to loosen the soil and any obstruction material prior to the installation of PVD. The obstruction clearance procedure is subjected to the approval of the Engineer; however, such, approval shall not relieve the Contractor of his responsibility to clear obstructions in accordance with the specification. If augering is the selected method, the augers shall have a minimum outside diameter equal to the largest horizontal dimension of the mandrel, shoe or anchor, whichever is greater.

iii) Additional Surcharge / Pre-Load

- a) Addition of surcharge load by approved embankment material shall be placed over the geotextile layer up to a height as per the design requirement.
- b) The addition of surcharge shall be placed with adequate side slope to avoid any slope failure.
- c) The addition of surcharge shall be kept in place for a period as per the design to achieve desired degree of consolidation. After ascertaining that the desired degree of consolidation is achieved, the addition of surcharge which is not forming part of permanent work/ embankment shall be removed to the required level as per drawings

- d) Removal of additional surcharge material shall be done without damaging the road embankment. After removal of additional surcharge, the damaged embankment top, if any, shall be made good as instructed by the Engineer

iv) Instrumentation and Monitoring

Monitoring the behavior of the sub-soil/ embankment construction shall form part of the work. The design shall be based on the gain in the shear strength of the subsoil due to consolidation process. The following critical parameters shall be monitored:

- a) Casagrande open standpipe type / Vibrating Wire type piezometer shall be used for measurement of pore pressure depending upon the requirement of the project and approval of Engineer in Charge. The detail specifications of the piezometer type along with calibration certificates as well as method statement for installation and monitoring will have to be submitted to the Engineer prior to commencement work.
- b) Settlements shall be measured by installing platform type settlement gauges, which consisting of a Wooden base plate of at least 1000 mm square and 50 mm thick; GI pipe of at least 25 mm dia fitted to the base plate with a suitable sleeve arrangement and nuts and bolts and Outer loose-fitting sleeve, to prevent soil from coming into contact with the inner pipe. Settlement gauges shall be installed at the ground level, before the starting of the fill construction. These shall be installed locations specified by the Engineer. The readings of settlement gauges also form the basis to estimate the quantity of surcharge forming part of permanent work. The number of settlement gauges shall be decided by the Engineer keeping in view this aspect.
- c) The shear strength parameters of the subsoil [unconfined compressive strength (UCS)] shall be measured at locations specified by the Engineer at the end of specified stage of surcharge loading in order to compare the actual details with the design assumptions. Alternate methods for determining shear strength may also be adopted based on proposal of the contractor subjected to approval of the Engineer.
- d) During the placing of the surcharge and compaction, the Contractor shall take utmost care so that the monitoring instruments are not damaged. Compaction by small vibratory rollers shall be done for 1.5 m around the monitoring instruments and bigger rollers shall not be used near the monitoring instruments. Similarly, care shall be taken that movement of dumpers does not damage the monitoring instruments.
- e) The readings of the piezometers and the settlement gauges shall be recorded at the following frequency.
 - Daily reading shall be taken in stretches where filling/ surcharge operations are in progress. Weekly readings shall be taken in stretches, where no filling/ surcharge is being done.
 - Weekly readings shall be taken after the desired fill/ surcharge height is achieved, till the next stage filling commences. All data shall be recorded in a register and maintained properly.
 -
 - The Data from the monitoring instruments provides the background for regulating the rate of placing the fill/ surcharge as well as the waiting period between stages

The water which will come out from the subsoil through vertical drains will be accumulated at temporary ditches to be dug at nearby areas and the accumulated water will be dewatered

regularly from the ditches to the outfalls as directed by the Engineer.

f) The water which will come out from the subsoil through vertical drains will be accumulated at temporary ditches to be dug at nearby areas and the accumulated water will be dewatered regularly from the ditches to the outfalls as directed by the Engineer.

2.13.3.3 Measurement and Payment

Rate shall include cost of materials, installation, operations involved in pre- loading/additional surcharge, dewatering, labor, plant hire, material storage and handling expenses for completing the work including submission of construction drawings and provision of specialist attendance & supervision at site for (i) geodrain; (ii) sand blanket; (iii) geofabric;(iv) instrumentation and monitoring; and (v) permanent embankment part of surcharge as described above.

Pay Item No.	Description	Unit Measurement
2/13/3/1	Prefabricated Vertical Drains	Lin meter
2/13/3/2	Geo-textile fabric – separation (non-woven)	Square meter
2/13/3/3	Geo-textile fabric – high strength one way (woven)	Square meter
2/13/3/4	Geo-textile fabric – high strength two way (woven)	Square meter
2/13/3/5	Granular drainage blanket.	Cubic meter
2/13/3/6	Multilinear geo-composite drain	Square meter
2/13/3/7	Settlement measuring instrument including plate, settlement pin, Piezometer, Inclinator	Nos.
2/13/3/8	Placement of Preload (Surcharge) which will be removed	Cubic meter

2.13.4 SAND COMPACTION PILE (SCP)

2.13.4.1 Description

The sand compaction pile (SCP) method is used to strengthen soft/loose ground by installing sand or a similar material into the soft ground via a casing pipe and vibrating the sand to produce firmly compacted sand piles in the ground. The method's basic improvement principles are "compaction" and "drainage".

This Specification covers the requirements for the installation of Sand Compaction Pile plus the associated works for the purpose of creating a composite ground with higher shear strength

values. Meanwhile, while using the application for sandy soil, the method is used for decreasing void ratio and creating soil with high density, high bearing capacity, and high resistance to liquefaction.

The Contractor shall provide all necessary resources including skilled labor, proper machine/tools, and materials to complete all the scope of works for the installation of SCP in accordance with the approved method statement, shop drawings, and this specification. Any alternate methods proposed by the contractor shall be at the discretion of Engineer and will have to be prior approved before commencement of work.

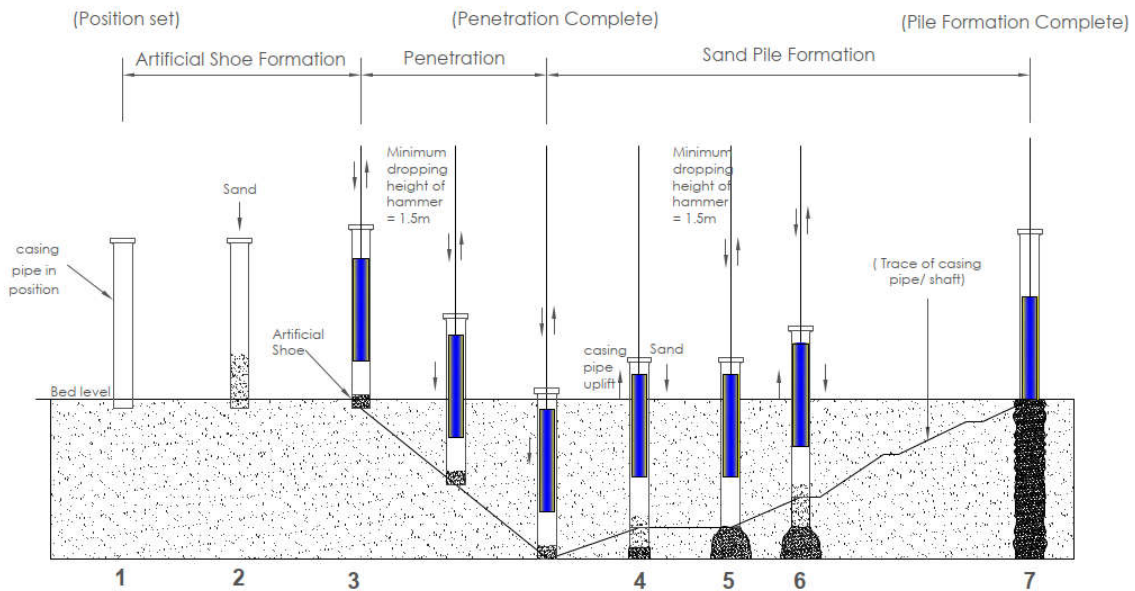


Figure 13-5. Procedure of Sand Compaction Pile

2.13.4.2 Materials

The material and equipment used for testing shall be prior approved by the Engineer

- i) Sand: Grading for the Sand Column shall conform to one of the grading envelopes A or B of Improve subgrade. FM of the sand shall not be less than 0.8.
- ii) Steel Casing Pipe: The casing pipe shall be of mild steel. The casing pipe length shall have at least 2m more length than the Sand Pile.
- iii) Drop Hammer: Solid cylinder-shaped drop hammer having at least 1 ton weight and sectional area that can play within the casing pipe shall be used for compaction. Diameter of hammer section shall be around 6mm to 8mm lower than the opening of the casing pipe.

2.13.4.3 Construction and Installation Requirements

The Contractor shall prepare and submit a method statement for installation of Sand Compaction Pile (SCP) and the associated works along with Drawings to the Engineer for prior written approval before the commencement of work

- a. A two-end open casing pipe of specified diameter and length will be placed vertically at the designed point of natural ground surface for sand pile construction

- b. A small hole of about 50mm / 100mm depth shall be made on the ground with the hammer. Casing pipe shall be held in a position with the wire rope connected to the winch, i.e., downward movement of the casing pipe shall be restrained
- c. Sand shall be placed within the casing pipe up to a depth of about 1m. Sand placed at the tip of the casing pipe shall then be compacted to form a solid mass (artificial shoe) by the hammer holding the casing pipe in position.
- d. Casing pipe shall then be allowed to go downwards with the application of hammer blows (minimum dropping height of hammer shall be greater than 1.5m) on the artificial tip and shall be penetrated up to the desired design depth.
- e. As the casing pipe reaches the desired depth, the pipe shall be pulled back by about 300mm from the lowest point and then held firmly from the winch. Artificial shoe shall be then detached from the casing pipe with the hammer blows. Sand shall be discharged into the casing pipe up to a depth of about 450 – 600mm
- f. The discharged sand shall be compacted and enlarged by driving the hammer numerous times into the sand.
- g. After proper compaction, the casing pipe shall be pulled back about 300mm, and sand shall be discharged and then compacted again.
- h. Pipe raising, sand discharging, and hammer driving procedure is repeated numerous times until the casing pipe reaches the ground surface, forming a complete compacted sand pile.

Quality Control

- a) During the construction, the depth of casing pipe and position of the sand in the casing pipe are continuously measured for quality control and assurance.
- b) The volume of sand measured on the ground, shall be between 135% to 150% of the designed value.
- c) Effect of improvement of the foundation shall be confirmed by SPT or any other method approved by the Engineer amongst the center of four piles to satisfy the bearing capacity requirements.

2.13.4.4 Measurement and Payment

The rate shall include the cost of providing all materials, tools, equipment, labor, supervision, and incidentals necessary to complete the work as per these specifications

Pay Item No.	Description	Unit Measurement
2/13/4	Execution of sand compaction pile through displacement method by using tripod rig, mechanical winch, dop hammer (minimum 1 ton), casing pipe up to a depth of 10m	Linear Meter

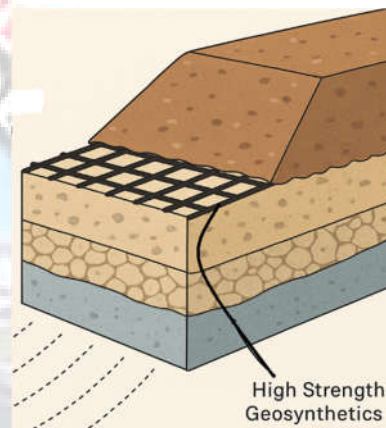
2.13.5 High-Strength Soil Reinforcement Geosynthetics

2.13.5.1 Description

High-strength soil reinforcement geosynthetics are advanced synthetic materials used in civil engineering and geotechnical applications to reinforce and stabilize soil, subgrades, embankments, and other structures. They enhance the load-bearing capacity of weak soils and prevent deformation, making them ideal for subgrade stabilization, road construction, and slope reinforcement.

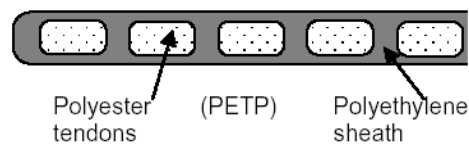
Application:

- a) **Basal Reinforcement:** High-strength soil reinforcement geosynthetic is used as basal reinforcement in layers or as a flexible mattress for ground improvement works for airport runways, railways, access roads and working platforms, hardstands, heavy-duty port pavements, and similar applications.
- b) **Embankment on Soft to Very Soft Soil:** High-strength soil reinforcement geosynthetic can be used as a reinforcing layer for the construction of embankments on poor sub-soils for improving stability. It helps in reducing the construction time and increases the global performance of the project. Embankment foundations reinforced with high-strength geosynthetics can withstand high static and dynamic loads.
- c) **Load Transfer Platforms and Piled Embankment:** High-strength soil reinforcement geosynthetic, when used in the ground improvement process of access roads for heavy load movements and for load-bearing platforms, induces stiffness to the soil underneath, improves lateral restraint, reduces the applied load on the soft soil, and controls the differential settlement. It is used in the transition layer for the distribution and transfer of load to rigid inclusions like sand/ stone columns or piles in soft foundations, and optimizes the requirement of such rigid inclusions.



2.13.5.2 Material

Bi-planar anisotropic soil reinforcement geosynthetic product assembled from co-extruded and oriented high tensile geosynthetic strips consisting of discrete channels of closely packed high tenacity polyester tendons (PET) encased in linear low-density polyethylene sheath, and together weft-welded to cross strips made from low shrinkage yarns to generate an orthogonal structure. The principal direction strips can have either smooth edges or trapezoidal teeth on both edges.



The soil reinforcing elements shall have the following certifications:

- CE Certification or Equivalent
- (ISO-9001), (ISO-45001) and (ISO-14001) or Equivalent
- Environmental Product Declaration (EPD)

Table 13-6 : Technical Specifications of High-strength Soil Reinforcement Geosynthetics

Mechanical Properties									
	Units	Values	Values	Values	Values	Values	Values	Values	Values
Nominal Tensile Strength	kN/m	300	400	500	600	700	800	900	1000
Elongation at Nominal Strength	%	≤ 12							
Tensile Strength at 2% Strain	kN/m	$\geq 18\%$ of Nominal Tensile Strength (Test Method: ISO-10319)							
Tensile Strength at 3% Strain	kN/m	$\geq 25\%$ of Nominal Tensile Strength (Test Method: ISO-10319)							
Tensile Strength at 5% Strain	kN/m	$\geq 43\%$ of Nominal Tensile Strength (Test Method: ISO-10319)							
Partial Reduction Factor - Creep ⁱ	@20° C	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Partial Reduction Factor – Installation Damage	D ₅₀ 0.9m m	0.99	0.99	1.0	1.0	1.0	1.0	1.0	1.0
	D ₅₀ 5.0m m	0.98	0.98	1.0	1.0	1.0	1.0	1.0	1.0
	D ₅₀ 21.0m m	0.99	0.99	1.0	1.0	1.0	1.0	1.0	1.0

Partial Reduction Factor – Environmental Effects ⁱⁱ	-	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Physical Properties									
Polymer on the Tensile Element	-	High Tensile Polyester (HT-PET)							
Polymer sheathing on the Tensile Element	-	Linear Low-Density Polyethylene (LLDPE)							
MD and CD Strap Distance (a/b)	mm/m	235/1000	201/1000	245/1000	201/1000	171/1000	152/1000	134/1000	120/1000
Aperture (X/Y)	mm/m	165/955	131/955	175/955	131/955	101/955	82/955	64/955	50/955
MD Strap Width	mm	70	70	70	70	70	70	70	70
Nominal Roll Width	m	≤5.7							
Selvages (Z)	mm	≤50							

- i. Reduction Factors are at 20°C and for 114 years of design life. Reduction factors for higher temperatures up to 40°C can be furnished on request.
- ii. Partial factors - environmental effects are valid for a pH range of 2 to 9.

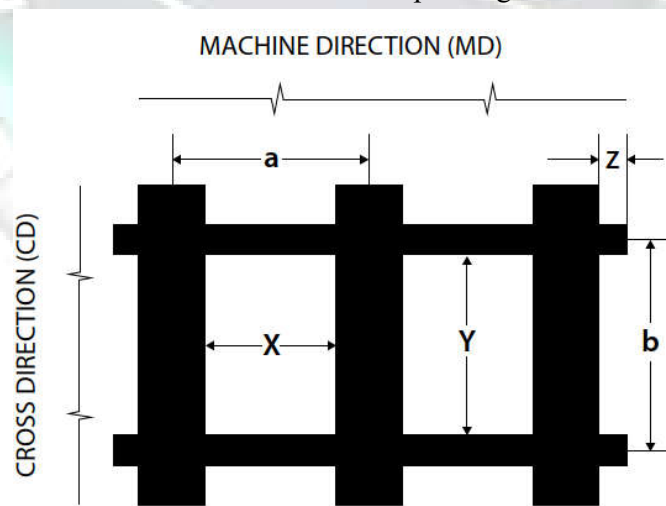


Fig 13-6: Aperture dimension

2.13.5.3 Identification, Storage and Handling

- a) High-strength geosynthetics are supplied in rolled form with a core with sufficient strength to avoid collapse or other damage during transportation, handling, lifting and installation.

Each roll is wrapped with plastic to protect it from damage during shipping and handling. Each roll is identified with a label, legible on the outside of the wrapping. The label indicates the grade strength, roll number and other intrinsic characteristics of the material, such as weight, width, length, etc

- b) Immediately before installation, the rolls should be inspected to ensure it is free of any damage that might have occurred prior to delivery. During the process of unloading or transferring the rolls from one location to another, care should be taken to prevent damage to the wrapping, core, label, or the roll itself.
- c) The storage location should have proper drainage and be situated away from low-lying areas or areas susceptible to water stagnation due to water leakages.
- d) The storage area should be properly levelled. It should be ensured that the storage area is capable of supporting the load of the stacks.
- e) The entire storage yard should be designated a “No Smoking Zone”. Adequate numbers of fire extinguishers shall be available inside the storage area.

2.13.5.4 Site Preparation

- a) The installation footprint shall be clear and demarcated. Trees, shrubs, stumps, protruding rocks and deleterious material should be removed from the site.
- b) The ground shall be leveled and proof-rolled to the desired finished level as per approved construction drawings.
- c) A drainage and separation layer comprising either a non-woven geotextile or multilinear geo-composite shall be laid as indicated in the approved drawings.

2.13.5.5 Installation Procedure

- a) The reinforcement shall be laid as shown in the construction drawings. The surface shall be cleaned, leveled, and preferably proof-rolled before laying the soil reinforcement.
- b) The reinforcement shall be installed per the installation guidelines contained in this document or as directed by the Engineer-in-Charge.
- c) The reinforcement shall be laid in the direction specified in the construction drawings. The installed length of the reinforcement in the cross-section shall be field checked. Overlaps between rolls shall be followed according to the recommendations contained in this document or as directed by the Engineer-in-Charge. Any obstacles or slack in the reinforcement shall be removed before backfill placement.



Fig 13-7: Typical Installation Procedure

d) Under no circumstances shall any construction traffic be allowed to operate directly over the installed roll. A fill cover measuring at least 300mm in thickness shall be placed above the installed roll before any equipment movement is allowed. Sharp turns shall not be allowed for any equipment operating over the fill.

e) For foundation soil with $CBR > 5$, a minimum overlap of 300mm is recommended. Overlaps for foundation soil with lower CBR values shall be recommended by the Engineer-in-Charge.

f) After the roll has been placed, it should be secured by weighting, pinning or other suitable methods to secure the free end of the reinforcement.

2.13.5.6 Measurement for Payment

The high-strength soil reinforcement geosynthetics shall be measured in Square meters as per planned dimensions with no allowance for overlapping at joints, anchoring at the toe and crest of the embankment. Excavation, backfill, bedding and cover material shall be measured separately as per relevant clauses of the Specifications.

2.13.5.7 Rate

The contract unit rate for the accepted quantities of high-strength geosynthetics in place shall be in full compensation for furnishing, preparing, hauling, and placing geosynthetics, including all labor, freight, tools, equipment, and incidentals to complete the work as per specifications.

Pay Item No.	Description	Unit Measurement
2/13/5/1	Supply and laying of bi-planar anisotropic high-strength soil reinforcement geosynthetics having nominal tensile strength of 300 KN/m to 1000KN/m (As per project requirement) and	Square meter

	made from 70mm (+/- 1mm tolerance) co-extruded high tensile polymeric strap soil reinforcement consisting discrete channels of closely packed high tenacity polyester (PET) yarns encased in Linear Low-Density Polyethylene (LLDPE) sheath with smooth edges and together weft welded to cross strips made from low shrinkage yarns to generate an orthogonal structure.	

2.14.1 GEOSYNTHETICS FOR ROAD AND BRIDGE WORKS

2.14.1.a Application and General Requirements

The specification covers the various applications of geosynthetic materials for use in road and bridge works including supplying and laying as per contract specifications. Geosynthetic is a general classification for all synthetic materials used in geotechnical engineering application. It includes geotextiles, geogrids, geo strips, geomembranes, recomposites, geosynthetic mats, paving fabric and glass grid etc. Geo fabrics made from natural fibers such as jute, and coir referred to herein under natural geotextiles may also be used in different geotechnical engineering applications.

- i) **Geotextiles:** Any permeable synthetic textile used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of a human made project, structure, or system. The geotextile fabric shall be a woven, non-woven or knitted fabric consisting of long-chain polymeric filaments or yarns such as polypropylene, polyethylene or polyester or any combination thereof, formed into a stable network such that the filaments or yarns retain their relative position to each other.

There are several application areas for geotextiles requiring specific functions namely separation, filtration, drainage, reinforcement or a combination thereof.

- ii) **Geogrids:** A deformed or non-deformed netlike polymeric material used with foundation, soil, rock, earth, or any other geotechnical engineering- related material as an integral part of human-made project, structure, or system.

Geogrids have relatively high strength, high modulus, and low-creep-sensitive polymers with apertures varying from 10 to 100 mm in size or more. The openings/holes in geogrids are either elongated ellipse, near squares with rounded corners, squares or rectangles. Geogrids can be of uni-axial grid, bi-axial grid or three-dimensional grids. Geostrip is another form of geogrid, which is used in reinforced soil structures. It is primarily made of synthetic material in strips and is made from high tenacity polyester yarn and contained in a suitable polymer sheath.

These are used as reinforcement in pavements and reinforced soil slopes.

- iii) **Geomembranes:** An essentially impermeable membrane (liner or barrier) used with foundation, soil, rock, earth, or in any other geotechnical application as an integral part of human-made project. Geomembranes are made from PVC or polyethylene sheets, which are duly protected from ultraviolet exposure by carbon black or any antioxidants and thermal stabilizers. These are used as capillary cut off in roads in water logged areas.
- iv) **Geonets:** Geonets are used in combination with other types of geosynthetics. These are usually formed by continuous polymeric ribs at acute angle to one another. When the ribs are opened relatively large size apertures are formed in a net like configuration. These are used in combination with other geosynthetic materials to form a composite material.
- v) **Geocomposite:** A manufactured material, which could be a combination of any two or more synthetic materials like geotextiles, geogrids, geonets and geomembranes etc., in laminated or composite form. One of the popular forms of geocomposite is Drainage Composite. Drainage Composites are formed by combining geotextile or geomembrane with a core of geonet or serrated/corrugated polymeric materials. Prefabricated Vertical Drains (PVD)/Band Drains and Fin Drains come under the category of geocomposites.
- vi) **Geosynthetic Mats:** These are two dimensional or three-dimensional mats with specified thickness, made of multi-filaments, with apertures to allow vegetation growth for erosion control application. Geosynthetic mat consists of UV stabilized non-degradable polypropylene/polyethylene or similar polymer fibers that are extruded or heat bonded to provide a dimensionally stable matrix. A tension element like steel wire mesh or geogrid shall be included in these mats as reinforcement, where these mats are required to possess more strength against erosive forces, like in steep slopes or in heavy rainfall areas. These are used for erosion protection of slopes.
- vii) **Natural Geotextiles:** These geotextiles are made of natural fibers like jute or coir. The blankets/mats/mesh made of these fibers are sometimes further reinforced with polymeric nettings to enhance its tensile strength and for holding the fibers intact. The polymer netting is securely stitched on both sides of the fabric to form a strong quilted mat. These fabrics have excellent drapability and aid in quick growth of vegetation and are used for erosion control applications
- viii) **Paving Fabric and Glass Grids:** The paving fabrics are non-woven heat set material, consisting of at least 85% by weight of polyolefins, polyester or polyamides. They are heat bonded only on one side.

Glass grids are either a composite glass fiber reinforced geogrid with continuous filament nonwoven geotextile chemically /mechanically bonded to the grid, or bituminous coated glass fiber geogrids with or without adhesive on one side of the grid.

The paving fabric, glass grids and composite of fabric and glass grids are used in bituminous pavements to act as stress relieving membrane and crack retarding layer within the pavement structure. The paving fabric also serves the function of water barrier.

- ix) **Multilinear Geo-composite Drainage:** Multilinear geo-composite drainage comprises of one or two non-woven geotextile filter layers and a drainage mat of polypropylene geotextile, and a series of perforated polypropylene mini-pipes of specified diameter arranged across the width at regular intervals. These components are securely bonded using a unique needle-punching technique. These systems are designed to collect, channel, and discharge water efficiently from soil structures while maintaining separation and filtration, and act as the subsurface drainage system.

Multilinear geo-composite drainages are installed along the slope or at the base of the highway and road embankment to relieve pore water pressure and improve slope stability by reducing water buildup in soft subgrade or fill soils. These are placed behind the retaining walls, reinforced earth walls, and bridge abutments to intercept groundwater, prevent hydrostatic pressure buildup, and manage seepage through embankment. The manufacturer shall have CE or Equivalent certifications.

2.14.1.b Testing, Certification and Acceptance

Geosynthetic Materials Shall be Tested and Certified in the Following procedure.

- a) The manufacturer shall have ISO certification for manufacturing process, quality control and environmental management systems.
- b) The manufacturer shall provide manufacturer's test certificate for every lot supplied from the factory.
- c) The supplier shall provide third party test reports from an independent laboratory with valid accreditation for all the test values in Manufacturer's test certificate.
- d) Geosynthetics shall be tested in accordance with tests prescribed by either by ASTM, EN, BS or ISO shall be conducted.
- e) The material shall meet the requirements as specified in the contract.

2.14.1.c Marking

Geosynthetic rolls shall be marked with the following information:

- a) Manufacturer's name
- b) Roll number
- c) Grade
- d) Length
- e) Date of manufacture; and
- f) Product identification details

2.14.1.d Packing, Storage and Handling

- a) Each geosynthetic roll shall be wrapped with a material that will protect the geosynthetic from damage due to shipment, water, sunlight and contaminants. The protective wrapping with a tarpaulin or opaque plastic sheet shall be maintained during periods of shipment and storage.
- During storage, geosynthetic rolls shall be elevated off the ground and adequately covered to protect from site construction damage, precipitation, prolonged ultra-violet radiation including sunlight, chemicals that are strong acids or strong bases, flames including welding sparks, temp temperature in excess of 71 degree centigrade , and any other environmental condition that may damage the physical properties of the geosynthetics.
- b) If the outer layer of the geosynthetic is damaged, or exposed to sunlight for a period beyond that is permitted the outermost wrap of the rolls shall be discarded, and only the remaining undamaged/unexposed material shall be used. If the geosynthetic rolls become wet, the water proof cover shall be removed, the rolls shall be elevated off the ground and exposed to wind in order to dry the fabric. The paving fabric used with bitumen overlays shall be completely dry prior to installation.

2.14.2 GEOTEXTILES FOR DRAINAGE, SEPARATION AND EROSION CONTROL

2.14.2.a Scope

The work covers the use of geotextile materials for drainage, separation/filtration and erosion control works including supplying and laying as per design, drawing and these specifications.

For drainage/filtration function, geotextile shall be able to convey water across the plane of the fabric throughout its design life. For separation function the geotextile shall prevent intermixing of two layers of dissimilar materials, throughout the design life of the structure.

The geotextile as a filter material below erosion control measures like stone pitching or stone filled mattresses over the slopes, shall allow the water to flow out and at the same time prevent the loss of soil under the protective measures.

2.14.2.b Material

a) Strength Requirement

The minimum strength of geotextile in terms of MARV under different installation conditions shall be as specified in Table 14-1

Table 14-1 : Minimum Geotextile Strength Property Requirements

Installation Condition	Type	Strength Property Requirement (MARV)							
		Grab Strength in Newton (N) as per ASTM D 4632	Tear Strength in Newton (N) as per ASTM D4533		Puncture Strength in Newton (N) as per ASTM D 6241		Burst Strength in Newton (N) as per ASTM D 3786		
		Elongation at Failure							
		<50 %	>50 %	<50 %	>50 %	<50 %	>50 %	<50%	>50%
Harsh installation condition	Type I	1400	900	500	350	2800	2000	3500	1700
Moderate Installation condition	Type II	1100	700	400	250	2250	1400	2700	1300
Less Severe Installation condition	Type III	800	500	300	180	1700	1000	2100	950

Note:

- 1) All numeric values in the above table represent Minimum Average Roll Value (MARV) in weaker principal direction. The MARV is derived statistically as the average value minus two standard deviations.
- 2) When the geotextiles are joined together by field sewing, the seam strength shall be at least 60 percent of the material's tensile strength. All field seams shall be sewn with thread as strong as the material in the fabric.

b) Ultraviolet Stability Requirements

The material shall satisfy the ultraviolet stability requirements specified in Table: 14-2.

Table 14-2 : Requirements for Ultra Violet Stability

Sl. No.	Properties of Fabric	Requirements (Retained Strength)
1)	Grab Strength	Not less than 70% after 500 hours of exposure
2)	Tear Strength	
3)	Puncture Strength	
4)	Burst Strength	

c) Hydraulic Requirements for Various Applications

i) Subsurface Drainage

The geotextile shall conform to the physical requirements specified in Table 14-3.

Table 14-3 : Geotextile Requirements for Subsurface Drainage

In-situ Passing 0.075 mm Sieve(%)	Permittivity, per sec, as per ASTM D 4491	Maximum Apparent Opening Size, mm ASTM D 4751/IS:14294-1995
<15	0.5	0.43
15 to 50	0.2	0.25
>50	0.1	0.22

The type of geotextile shall be decided by the Engineer depending upon the installation conditions.

ii) Separation

The geotextile for different subgrade soil conditions shall conform to the requirements given in Tables 14-4 and 14-5.

Table 14-4 : Geotextile Requirements for Separation (Subgrades Soaked CBR >3)

S. No.	Geotextile Property	Requirement
1)	Permittivity as per ASTM D 4491	0.02 sec ⁻¹ (per sec)
2)	Maximum Apparent Opening Size as per ASTM D 4751	0.60 mm

Table 14-5 : Geotextile Requirements for Separation (Subgrades Soaked CBR ≤3)

S. No.	Geotextile Property	Requirement
1)	Permittivity as per ASTM D 4491	0.05 sec ⁻¹ (per sec)
2)	Maximum Apparent Opening Size as per ASTM D 4751	0.43

iii) Erosion Control

The geotextile for erosion control shall conform to requirements given in Table 14-6.

Table 14-6 : Geotextile Requirements for Erosion Control

In-situ Soil Passing 0.075 mm Sieve(%)	Permittivity, per sec ASTM D 4491	Maximum Apparent Opening Size, mm ASTM D 4751
<15	0.5	0.43
15 to 50	0.2	0.25
>50	0.1	0.22

2.14.2.c Construction

2.14.2.c.1 General

Exposure of geotextiles to the elements between lay down and cover shall be a maximum of 14 days to minimize damage potential. In trenches, after placing the backfill material, the geotextile shall be folded over the top of the filter material to produce a minimum overlap of 300 mm for trenches greater than 300 mm wide. In trenches less than 300 mm wide, the overlap shall be equal to the width of the trench. The geotextile shall then be covered with the subsequent course. Overlap at roll ends and at adjacent sheets shall be a minimum of 450 mm, except when placed under water. In such instances, the overlap shall be a minimum of 1 m. Where seams are required in the longitudinal trench direction, they shall be joined by either sewing or overlapping. All seams and overlaps shall be subject to the approval of the Engineer.

Care shall be taken during installation so as to avoid any damage to the geotextile. Damages, if any, during installation shall be repaired by placing a geotextile patch over the damaged area and extending it 1m beyond the perimeter of the tear or damage, or as approved by the Engineer.

2.14.2.c.2 Subsurface Drainage

Construction shall conform to the specifications.

2.14.2.c.3 Separation

After preparation of subgrade as per the specifications along the road alignment, geotextile shall be rolled out as indicated in the drawings. The entire roll shall be placed on the sub grade and unrolled as smoothly as possible. Wrinkles and folds in the fabric shall be removed by stretching as required. Adjacent rolls of geotextiles shall be overlapped, sewn, or joined as required. For curves, the geotextile shall be folded or cut and overlapped in the direction of construction. Folds in the geotextile shall be stapled or pinned approximately 0.6 m centre-to-centre. Before covering, the condition of the geotextile shall be checked for damage (i.e., holes, nips, tears, etc) by the Engineer. Before placing the first lift of granular sub-base on the geotextile, a trial stretch of 100 m shall be laid as per roll width to establish a proper construction methodology of placing and compacting the sub-base in a manner that no damages are caused to the separation layer of geotextile.

2.14.2.c.4 Filter Layer under Stone Pitching for Erosion Control

The geotextile shall be placed in intimate contact of soil ensuring slight tension, to avoid wrinkles or folds and shall be anchored on a properly shaped surface as indicated in drawings and approved by the Engineer. It shall be ensured that the placement of the overlying material be placed in such a manner that it does not tear/puncture the geotextile. Anchoring of the terminal ends of the geotextile shall be accomplished as per drawings through the use of key trenches or aprons at the crest and toe of slope.

The geotextile shall be placed with the machine direction parallel to the direction of water flow. Adjacent geotextile sheets shall be joined by either sewing or overlapping. The pitching shall begin at the toe and proceed up the slope. Big sized boulders shall not be allowed to roll down the slope. Any geotextile damaged shall be either replaced or repaired with a patch, as directed by the Engineer, at the cost of the contractor.

2.14.2.d Measurement for Payment

The measurement for payment of Geotextile for sub surface drains shall be in square metre along with drain construction and drain construction will be separate item.

The geotextile for separation and for filter layer shall be measured in square metres as per planned dimensions with no allowance for overlapping at transverse and longitudinal joints. Excavation, back fill, bedding and cover material shall be measured separately as per relevant clauses of the Contract.

2.14.2.e Rate

The contract unit rate for the accepted quantities of geotextile for drains, separation and filter layer in place shall be full compensation for furnishing, preparing, hauling, and placing geotextile including all labour, freight, tools, equipment, and incidentals to complete the work as per specifications.

2/14/1	Furnishing and installing Geotextile for sub-surface drain /separation / filter layer (as detailed in the Drawing or as directed by the Engineer)	Square metre

2.14.3 GEOGRID

2.14.3.a Scope

The work covers the use of geogrids in stabilizing of subgrade in embankment, sub-base of pavement, erosion control of slopes, reinforced soil slopes and reinforced soil walls including supplying and laying as per design, drawing and these specifications.

2.14.3.b Materials

2.14.3.b.1 General

Geogrids shall be either made from high tenacity polyester yarn jointed at cross points by weaving, knitting or bonding process with appropriate coating or from polypropylene or polyethylene or any other suitable polymeric material by an appropriate process. Geogrids manufactured by extrusion process are integrally jointed, mono or bi-directionally oriented or stretched meshes, in square, rectangular, hexagonal or oval mesh form. The geogrids manufactured by weaving/knitting/bonding process shall be formed into a stable network such that ribs, filaments or yarns retain their dimensional stability relative to each other including selvages.

2.14.3.b.2 Basal Reinforcement

Basal reinforcement refers to the use of high-strength geogrids at the subgrade of embankments, especially those constructed over soft or weak soils. High-strength geogrids

are advanced synthetic materials used in civil engineering and geotechnical applications to reinforce and stabilize soil, subgrades, embankments, and other structures. They enhance the load-bearing capacity of weak soils and prevent deformation, reduce differential settlements, making them ideal for subgrade stabilization, road construction, and slope reinforcement.

The design of basal reinforcement involves determining the type, strength, layout, and placement of geogrids at the subgrade of an embankment built over soft or weak soil. It depends on various factors like subsoil condition, embankment height, seismic coefficient, embankment fill properties etc.

Table 14-7 : Minimum Requirements for Geogrid as Basal Reinforcement

Mechanical Properties									
	Units	Values	Values	Values	Values	Values	Value s	Value s	Value s
Nominal Tensile Strength	kN/m	300	400	500	600	700	800	900	1000
Elongation at Nominal Strength	%	≤ 12							
Tensile Strength at 2% Strain	kN/m	$\geq 18\%$ of Nominal Tensile Strength (Test Method: ISO-10319)							
Tensile Strength at 3% Strain	kN/m	$\geq 25\%$ of Nominal Tensile Strength (Test Method: ISO-10319)							
Tensile Strength at 5% Strain	kN/m	$\geq 43\%$ of Nominal Tensile Strength (Test Method: ISO-10319)							
Partial Reduction Factor - Creep ⁱ	@20°C	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Partial Reduction Factor – Installation Damage	D ₅₀ 0.9mm	0.99	0.99	1.0	1.0	1.0	1.0	1.0	1.0
	D ₅₀ 5.0mm	0.98	0.98	1.0	1.0	1.0	1.0	1.0	1.0
	D ₅₀ 21.0mm	0.99	0.99	1.0	1.0	1.0	1.0	1.0	1.0
Partial Reduction Factor – Environmental Effects ⁱⁱ	-	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83

Physical Properties									
Polymer on the Tensile Element	-	High Tensile Polyester (HT-PET)							
Polymer sheathing on the Tensile Element	-	Linear Low-Density Polyethylene (LLDPE)							
MD and CD Strap Distance (a/b)	mm/mm	235/1000	201/1000	245/1000	201/1000	171/1000	152/1000	134/1000	120/1000
Aperture (X/Y)	mm/mm	165/955	131/955	175/955	131/955	101/955	82/955	64/955	50/955
MD Strap Width	mm	70	70	70	70	70	70	70	70
Nominal Roll Width	m	≤5.7							
Selvages (Z)	mm	≤50							

- i. Reduction Factors are at 20°C and for 114 years of design life. Reduction factors for higher temperatures up to 40°C can be furnished on request.
- ii. Partial factors - environmental effects are valid for a pH range of 2 to 9.

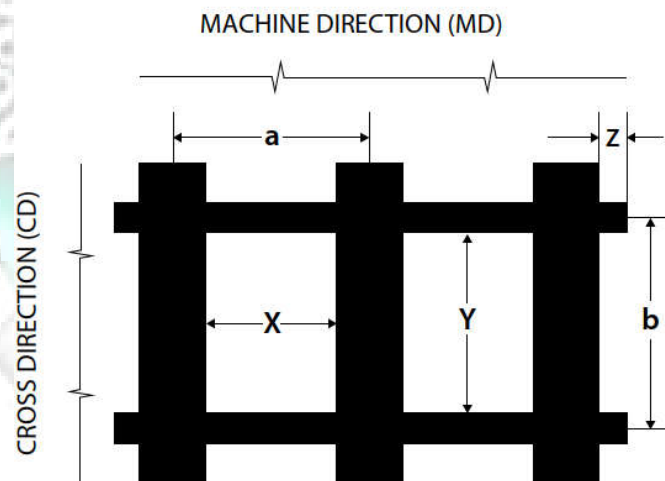


Fig 14-1: Aperture dimension

2.14.3.b.3 Sub-base Reinforcement

Geogrid for use as reinforcement of sub-base layers of flexible pavements shall meet the requirement as per the design subject to the minimum requirements as given in Table 14-8.

2.14.3.b.4 Erosion Control

The geogrid for erosion control application shall have the minimum tensile strength of 4 KN/m, when tested as per ASTM D5035 (Minimum Average Roll Value in Machine Direction). The aperture opening size shall be minimum 20 mm x 20 mm and average

grid thickness shall be minimum 1.0 mm. Geogrid for erosion control application shall be UV stabilized. The geogrid shall have ultraviolet stability of 70 percent after 500 hrs exposure as per ASTM D 4355.

Table 14-8 : Minimum Requirements for Geogrid for Sub-Base of Flexible Pavement

Property	Test Method	Unit	Requirement
Stiffness at 0.5% strain	ISO-10319	kN/m	≥ 350 ; both in machine and cross-machine direction
Tensile strength @2% Strain	ASTM D6637	kN/m	$\geq 15\%$ of T_{ult} ; both in machine and cross-machine direction
Tensile strength @5% Strain	ASTM D6637	kN/m	$\geq 20\%$ of T_{ult} ; both in machine and cross-machine direction
Junction Efficiency for extruded geogrids	ASTM-WK 14256	-	90% of rib ultimate tensile strength
Ultraviolet stability	ASTM D4355	-	70% after 500 hrs exposure

Note:

- 1) All numerical values in the Table represent MARV in the specified direction.
- 2) All geogrids shall be placed along machine direction parallel to the centre line of roadway alignment.

2.14.3.b.5 Reinforced Soil Slopes and Walls

The strength and other requirements shall be as per specification/design .

2.14.3.c Installation and Construction Operations

2.14.3.c.1 Basal Reinforcement



Figure 14-2: Typical arrangement of basal reinforcement below an embankment

The installation area shall be clear and demarcated. Trees, shrubs, stumps, protruding rocks and deleterious material should be removed from the site. The ground shall be leveled and proof-rolled to the desired finished level as per approved construction drawings. A drainage and separation layer comprising either a non-woven geotextile or multilayer geocomposite shall be laid as indicated in the approved drawings.

The reinforcement shall be laid in the direction specified in the construction drawings. The installed length of the reinforcement in the cross-section shall be field checked. Overlaps between rolls shall be followed according to the recommendations of the manufacturer's manual or as directed by the Engineer in charge. Any obstacles or slack in the reinforcement shall be removed before backfill placement.

Under no circumstances shall any construction traffic be allowed to operate directly over the installed basal reinforcement. A fill cover measuring at least 300mm in thickness shall be placed above the installed roll before any equipment movement is allowed.

2.14.3.c.2 Sub-base Reinforcement

Prior to laying of geogrid, the surface shall be properly prepared, cleaned and dressed to the specified lines and levels as shown on the drawings. The geogrid shall be laid within the pavement structure as shown on the drawings. Geogrid reinforcement shall be placed flat, pulled tight and held in position by pins or suitable means until the subsequent pavement layer is placed. No vehicle shall be allowed on geogrid unless it is covered by at least 150 mm thick sub-base material.

2.14.3.c.3 Erosion Control

The geogrid for erosion control applications shall be installed in accordance with the manufacturer's recommendation and as per Clause.

2.14.3.c.4 Reinforced Slopes and Walls

The geogrid for reinforced slopes and walls shall be installed in accordance with the manufacturer's recommendation.

2.14.3.d Measurement for Payment

The geogrid shall be measured in square metres as per planned dimensions with no allowance for overlapping at joints, anchoring at toe and crest of the slope. Excavation, back fill, bedding and cover material shall be measured separately as per relevant clauses of the Specifications. Reinforced soil slopes and walls shall be measured separately.

2.14.3.e Rate

The contract unit rate for the accepted quantities of geogrid in place shall be in full compensation for furnishing, preparing, hauling, and placing geogrid including all

labor, freight, tools, equipment, and incidentals to complete the work as per specifications.

2/14/1 Furnishing and installing Geogrid (as detailed in the Drawings or as directed by the Engineer) Square metre

2.14.4 GEO-COMPOSITE DRAIN

Specifications of PVD shall conform to specifications outlined under section 2.13.3

2.14.4.1 Description

The work covers the use of geo-composite drainage systems behind retaining walls, slopes, canals, pavement etc. The Contractor shall provide all necessary resources including skilled labor, proper machine/tools and materials to complete all the scope of works for installation of geo-composite drain as per specification based on the approved method statement. Any alternate methods proposed by the contractor shall be at the discretion of Engineer and will have to be prior approved before commencement of work.

2.14.4.2 Materials

Geo-composite drains for between fills and retaining wall: The geo-composite drain shall meet the requirements mentioned in the following table for application behind retaining wall and between two fills.

Table 14-8. Requirements of geo-composite drains

Properties	Test Method	Behind retaining wall	Between two fills
A) Geo-composite Drain Non-woven geotextile on both the sides			
Draining Core shape		Multifilament net or mat	Multifilament net or mat
Thickness at 2 kPa	EN 9863-1 or equivalent	7 mm (+/-10%)	8.9mm (-10%)
Mass per unit area* (This is not performance parameter)	ISO 9864 or equivalent	720 g/m ² (+/-15%)	990 g/m ² (± 10%)
Tensile Strength Machine Direction	ISO 10319 or equivalent	18 kN/m (- 5)	21 kN/m (- 1kN)
In plane flow capacity MD Hydraulic Gradient, i = 1 at 20 kPa pressure	ISO 12958 or equivalent	2.30 L / (m.s) (rigid/soft contact) (+/-30%)	3.7 L / (m.s) (soft/soft contact) (+/- 30%)

Reduction factor for creep for 100 years at 100kPa	ASTM D7361-07 & ISO 25619-1:2008 or equivalent	Not more than 1.15	Note more than 1.1
B) Geotextile Filter – Two Number			
Tensile Strength MD & CD	EN ISO 10319 or equivalent	8 kN/m (-1.3)	9.25 kN/m (-1.7)
Static Puncture Resistance	EN ISO 12236 or equivalent	1400 N (+/-20%)	1600 (-21%)
Dynamic Puncture Resistance	EN ISO 13433 or equivalent	26 mm (+22)	26 (+6)
Flux perpendicular to plane	EN ISO 11058 or equivalent	100 l/(m ² .s) (-30)	110 (- 30)
Apparent Opening Size, O ₉₀	EN ISO 12956 or equivalent	110 micron (+/-50)	100 (± 45)
C) Drainage Core			
Mass per unit area* (This is not performance parameter)	EN ISO 9864 or equivalent	500 g/m ² (+/-10%)	740 (± 5%)

Geo-composite drain for capillary cutoff: The geo-composite drain shall meet the requirements mentioned in the following table for capillary cut-off application in pavement and canal lining.

Properties	Test Method	Below pavement or horizontal application of capillary cutoff
Geocomposite (Non-woven geotextile on both the sides		
Draining Core shape		Multifilament net or mat
Thickness at 2 kPa	EN 9863-1 or equivalent	6 mm
Mass per unit area* (This is not performance parameter)	ISO 9864 or equivalent	670 g/m ² (± 10%)

Tensile Strength Machine Direction	ISO 10319 or equivalent	22 kN/m (- 3.0)
In plane flow capacity MD Hydraulic Gradient, $i = 0.1$ at 20 kPa pressure	ISO 12958 or equivalent	0.35 L / (m.s) (rigid/soft contact)
Reduction factor for creep for 100 years at 100kPa	ASTM D7361-07 & ISO 25619-1:2008 or equivalent	Not more than 1.15
B) Geotextile Filter – Two Number		
Tensile Strength MD & CD	EN ISO 10319 or equivalent	8 kN/m (-2.0)
Static Puncture Resistance	EN ISO 12236 or equivalent	1400 N (-20%)
Dynamic Puncture Resistance	EN ISO 13433 or equivalent	33 mm (+15)
Flux perpendicular to plane	EN ISO 11058 or equivalent	100 l/(m ² .s) (+/- 30)
Apparent Opening Size, O_{90}	EN ISO 12956 or equivalent	110 micron (+/- 50)
External Membrane	EN ISO 10319 or equivalent	16 kN/m (-2.0)
Mass per unit area	EN ISO 9864 or equivalent	120 g/m ² (-10%)
Tensile strength	EN ISO 10319 or equivalent	16 kN/m (-2.0)
C) Drainage Core		
Mass per unit area* (This is not performance parameter)	EN ISO 9864 or equivalent	430 g/m ² (+/- 7%)

Geo-composite drain shall be tested for long term creep at accredited laboratory like TRI / SGI / BTTG based on requirement of the Engineer and material having reduction factor for creep RF_{CR} only shall be used. Uncertified reduction factors or default reduction factors from any literature shall not be allowed to be adopted. Geo-composite drain shall be CE certified.

Geo-composite draining core and geotextile filter should not be cut from the drainage composite for testing purpose. The core and filter should be tested preferably prior to making a composite. For third party testing core and filter shall be separately collected from the manufacturer.

2.14.4.3 Construction and Installation Requirements

The Contractor shall prepare and submit method statement for installation of geo-composite drain before the commencement of work for the approval of Engineer.

- a. The geo-composite drain shall be provided in wraps with a protective covering. A tag or label, or other method of identification shall be attached to each wrapped package indicating the: Manufacturer Name, Product Name and Style, and Roll Identification Number. Rolls of geo-composite drain should not be dragged on the ground, and they must be lifted off the ground before moving them.
- b. Geo-composite drain should be adequately protected from ultraviolet (UV) exposure during storage at the site. The protective wrapping, in which the geo-composite drain come wrapped from factory, should be kept on till their installation. After unwrapping, the geo-composite drain should be installed within a maximum of 14 days. If stored outside, they should be elevated from the ground surface and adequately covered to protect them from site construction damage, precipitation, UV radiation, including sunlight, chemicals that are strong acid/bases, flames including welding sparks, temperature in excess of 71°C, etc.
- c. When geo-composite drains are assembled on site, the assemble area shall be clean and dry. Geo-composite shall have 100mm extra geotextile on side edges for overlap purpose. Joint parallel to the direction of flow and any exposed edge shall be protected from the ingress of soil by wrapping with a minimum overlap of 150mm or other measures.
- d. Geo-composite drains shall be capable enough of being connected longitudinally and laterally into pipe systems or outflow purpose. Joint parallel to flow direction and exposed soil shall be protected from ingress of soil by wrapping with a minimum overlap of 150mm or other necessary measures

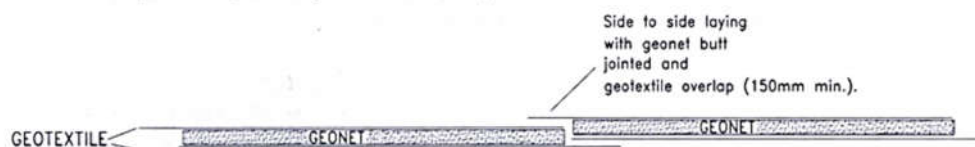


Figure 14-3: Ge-composite jointing and overlap

- e. In case of installation behind abutment / retaining wall slotted / perforated pipe may be provided for horizontal drainage at the bottom, by placing geotextile wrapping around the pipe

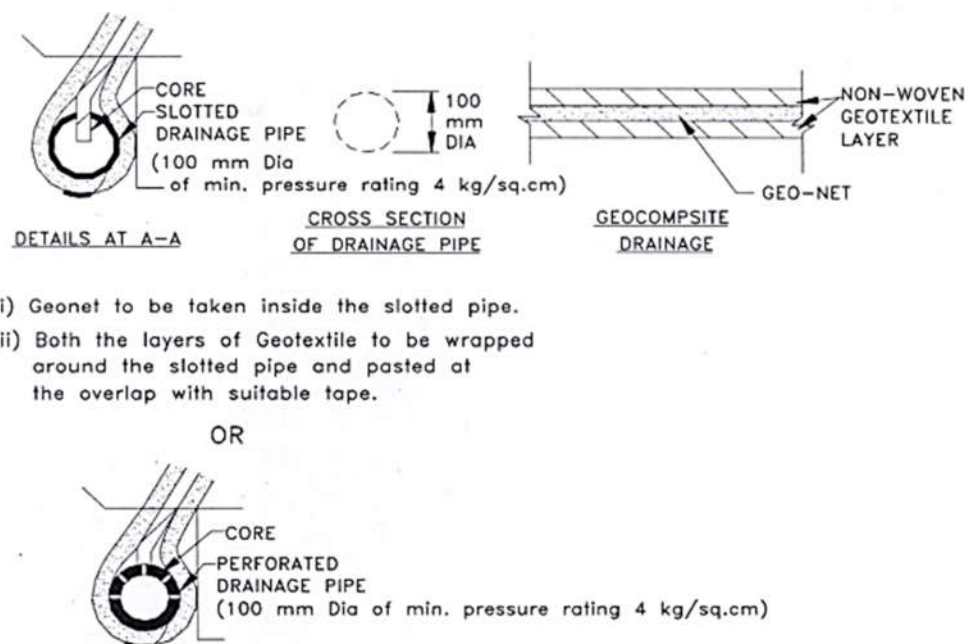


Figure 14-4. Details of Geotextile wrapping

- f. Installation of geo-composite drains for pavement and linings shall be as per ASTM D6088-06 ("Standard Practice for installation of geo-composite pavement drains") or other approved standards.

2.14.4.4 Measurement and Payment

The geo-composite drain shall be measured in linear meters as per planned dimensions with no allowance for overlapping at joints, anchoring at toe and crest of the slope/wall/embankment. Excavation, backfill, bedding and cover material shall be measured separately as per relevant clauses of the Specifications.

The contract unit rate for the accepted quantities of geo-composite drain in place shall be in full compensation for furnishing, preparing, hauling, and placing geocomposite including all labor, freight, tools, equipment, and incidentals to complete the work as per specifications.

Pay Item No.	Description	Unit Measurement
2/14/3	Geo-composite drain	Square meter

2.14.5 GEOSYNTHETIC MAT

2.14.5.a Scope

The work covers the use of geosynthetic mats for control of erosion of slopes including supplying and laying the mat, spreading soil and seeding to promote the design of vegetation, as per design, drawing and these specifications.

2.14.5.b Material and Strength Requirements

Geosynthetic mat shall be a three-dimensional structure consisting of UV stabilized non-degradable polypropylene, polyethylene, nylon or similar polymer fibres that are extruded or heat bonded at the contact points to provide a dimensionally stable matrix for soil erosion protection. A tension element, i.e. a reinforcing element like geogrid or steel wire mesh shall be included along with the three dimensional polymeric mats to provide strength against erosive forces, if specified in the contract

The tensile strength requirements for non reinforced and reinforced three dimension geosynthetics mat shall meet the minimum requirement as specified in Table 14-10 and Table 14-11 respectively.

2.14.5.c Installation

Prior to laying of geosynthetics mat on the slope, the surface shall be properly prepared, cleaned and dressed to the specified lines and levels as shown on the drawings. Specified trench keys along the crest and at the bottom of slope area shall be provided to fix the geosynthetics mat in the ground. In case the soil is not fertile, it shall be mixed with suitable amount of fertilizer or seeds.

Table 14-9 : Tensile Strength Requirement for Normal (Non-Reinforced) Three Dimensional .Geosynthetic Mat for Erosion Control Application (Less Severe Environmental Condition)

Property	Test Method	Units	Minimum Average Roll Value
Tensile strength requirement (For slopes less than 60 ⁰) For slopes up to 80 ⁰	ASTM D 5035	KN/m	2
Ultraviolet stability at 500h, Retained strength percentage with respect to original strength	ASTM D 4355	%	80
Thickness	ASTM D 6525	mm	6.5
Mass per unit area	ASTM D 3776	gm/m ²	250

Table 14-10: Tensile Strength Requirement for Reinforced Three Dimensional Geosynthetic Mat for Erosion Control Application (Severe Environmental Conditions)

Property		Test Method	Units	Minimum Average Roll Value
Tensile strength requirement	For slopes up to 60°	ASTM D 5035	KN/m	10
	For slopes up to 80°			35
Ultraviolet stability at 500h, Retained strength percentage with respect to original strength		ASTM D 4355	%	80
Thickness		ASTM D 6525	mm	12
Mass per unit area		ASTM D 3776	gm/m ²	500

The work of laying the mat shall begin at the top of the slope providing anchor blankets in a 300 mm deep and 300 mm wide trench and anchoring with staples/pins. The mat shall then be unrolled down the slope in the machine direction. The blanket shall not be stretched but shall have full contact with the soil. The blanket shall be anchored using staples or stakes.

Edges of adjacent parallel rolls shall be overlapped by approximately 100 mm to 120 mm and anchored with staples at 600 mm to 800 mm spacing depending on the slope. When blankets have to be spliced, the upper blanket end shall be placed over lower blanket end (shingle style) with 300mm overlap and anchoring with two staggered rows of staples at 300mm spacing. A minimum cover of soil shall be spread followed by spreading the seeds and fertilizer. In the absence of rain, blankets shall be regularly watered for viable growth till vegetation sustains on its own. If any damage due to heavy downpour is noticed, suitable corrective measures shall be taken immediately. Gully formations, if any, shall be suitably corrected depending upon the site condition. The treated area shall be protected from the movement of cattle (goat, sheep & cow). Grazing shall be avoided till the vegetation sustains on its own.

2.14.6.d Measurement for Payment

The geosynthetic mat shall be measured in square metre as per planned dimensions with no allowance for overlapping at joints, anchoring at toe and crest of the slope.

2.14.6.e Rate

The contract unit rate for geosynthetic mat for erosion control shall be in full compensation for furnishing and installing the specified materials and growth of vegetative cover in accordance with the contract documents including site preparation, and for furnishing all labor, tools, equipment and incidentals to complete the work as per these Specifications.

2/14/4 Furnishing and installing geosynthetic mat Square metres
(as detailed in the Drawings or as directed
by the Engineer)

2.14.7 NATURAL GEOTEXTILE

2.14.7.a Scope

The work covers the use of natural geotextile/es for control of erosion of slopes including supplying and laying the mat spreading soil and seeding to promote the growth of vegetation, as per design, drawing and these specifications. Natural Geotextile shall be used to control surface erosion of top cover soil on cut or fill slopes and to facilitate vegetation to grow.

2.14.7.b Strength Requirements

The natural fibre geotextiles made of Jute shall meet the minimum requirement as specified in Woven Jute Geotextiles- Specification. However, for coir fibre geotextile, it shall meet the requirements as specified in Table 14-12, when used for erosion control measures.

Table 14-11 : Typical Specifications of Natural Geotextile (MARV*) using Coir

Type of Price	Weight (gms)	Width (cm)	Thickness (mm)	Tensile Strength (kN/m)		Elongation at Break (%)	Water Holding Capacity (%)	Porosity Micron
				M D	CD			
Open Mesh. Fabric	300	120	4.0	5	2.5	20	-	-
Nonwoven Fabric	450	150	4.0	7.5	2.5	30	80	75

*Minimum average roll value

Alternatively, a biodegradable composite mattress can be used for protecting dry and intermittently wet and erodible slopes. Biodegradable erosion control mattress is a mechanically bonded erosion control blanket made from bio-degradable non-woven coconut fiber reinforced with closely woven very fine HDPE nets on both sides of the mattress having polymeric net on both sides. The detailed specification of the erosion control mat shall be as under;

Table 14-12 : Typical Specifications of Natural Geotextile using Coconut Fiber Coir Blanket

Property	Test Method	Unit	Value
Thickness	ASTM D6525	mm	7.5

Mass	ASTM D5261	g/m ²	600
Tensile Strength (Machine direction)	ASTM D6818	kN/m	8.0
Tensile Strength (Cross Machine direction)	ASTM D6818	kN/m	4.0
Elongation at max (Machine direction)	ASTM D6818	%	48
Elongation at max (Cross Machine direction)	ASTM D6818	%	50
CBR Puncture Strength	ASTM D6241	KN	1.35
Netting (HDPE, Light Weight)	All over both sides		
Matrix (100% Coconut Fiber)	600 g/m ²		

Hydroseeding and watering shall be done to support vegetation growth on the slope surface as per the climatic condition of the project site.

2.14.7.c Installation

Prior to laying of natural geotextiles on the slope, the surface shall be properly prepared, cleaned and dressed to the specified lines and levels as shown on the drawings. Specified trench keys along the crest and at the bottom of slope area shall be provided to fix the natural geotextile in the ground. In case the soil is not fertile, it shall be mixed with suitable amount of fertilizer or seeds. The work of laying the mat shall begin at the top of the slope providing anchor blankets in a 300 mm deep and 300 mm wide trench and anchoring with staples/pins. The mat shall then be unrolled down slope in the machine direction. The blanket shall not be stretched but shall have full contact with the soil. The blanket shall be anchored using staples or stakes. Edges of adjacent parallel rolls shall be overlapped by approximately 100-120 mm and anchored with staples at 600-800 mm spacing depending on the slope. When blankets have to be spliced, the upper blanket end shall be placed over lower blanket end (shingle style) with 300 mm overlap and anchoring with two staggered rows of staples at 300 mm spacing.

A minimum cover of soil shall be spread followed by spreading the seeds and fertilizer. A slow release supplementary fertilizer may be applied to speed up the growth of the vegetation. In the absence of rain, blankets shall be regularly watered for viable growth till vegetation sustains on its own. If any damage due to heavy downpour is noticed, suitable corrective measures shall be taken immediately. Gully formations, if any, shall be suitably corrected depending upon the site conditions. The treated area shall be protected from the movement of cattle (goat, sheep & cow). Grazing shall be avoided till the vegetation sustains on its own.

2.14.7.d Measurement for Payment

The natural geotextile shall be measured in square metres as per planned dimensions with no allowance for overlapping at joints, anchoring at toe and crest of the slope.

2.14.7.e Rate

The contract unit rate for natural geotextile mat for erosion control shall be in full compensation for furnishing and installing the specified materials and growth of vegetative cover in accordance with the contract documents including site preparation, and for furnishing all labour, tools, equipment and incidentals to complete the work as per these Specifications.

2/14/5 Natural Geotextile (as detailed in the Drawing Square metre
or as directed by the Engineer)

2.14.8 PAVING FABRICS/GLASS GRIDS

2.14.8.a Scope

This work shall consist of laying geosynthetic materials either non-woven paving fabric or fibre glass coated grid over existing bituminous surface, including preparation of surface and joining, stitching or overlapping of geosynthetic fabric etc. as part of highway pavement strengthening in layers as shown on drawings or as directed by the Engineer.

2.14.8.b Material Requirements

2.14.8.b.1 Paving Fabrics

The paving fabric will be a non-woven heat set material consisting of at least 85 percent by weight of polyolefins, polyesters or polyamides. The paving fabric shall be resistant to chemical attack, rot and mildew and shall have no tears or defects which will adversely alter its physical properties. The fabric shall be specifically designed for pavement applications and be heat bonded only on one side to reduce bleed-through of tack coat during installation. The fabric shall meet the physical requirements given in Table 14-13. Table 14-13: Physical requirements for Paving Fabrics (Minimum Average Roll Value)

Property	Units	Standard Requirements	Test Method
Grab Tensile Strength	N	450	ASTM D 4632
Elongation	%	≥ 50	ASTM D 4632
Mass Per Unit Area	gm/m ²	: 140	ASTM D 3776
Asphalt Retention	Kg/10 sq.m	10*	ASTM D 6140
Melting Point	°C	150	ASTM D 276
Surface Texture	-	Heat bonded on One side only	Visual inspection

Note:* the product asphalt retention property must meet MARV provided by the manufacturer.

2.14.8.b.2 Glass Grids

These will be either a composite glass fibre reinforced geogrid with continuous filament non- woven Geotextile chemically or mechanically bonded to the grid; or bituminous coated glass fiber geogrid with or without adhesive on one side of the grid. The physical and mechanical properties of glass grid fabric shall conform to the requirements given in Table 14-14.

Table 14-14 : Properties of Glass Fibre Grids

Property	Units	Requirement			
		Tensile strength both Median and Cross- Machine Direction			
Tensile strength	KN/m	ASTM D 6637	50	1000	200
% Elongation at break	%		>4	>4	>4
Minimum Mesh size	Mm		25x25	12.5x12.5	12.5x12.5
Melting point	°C	ASTM D 276	>250	>250	>250

2.14.8.b.3 Asphalt Reinforcing Geo-grids

These shall be made of high modulus polyester yarns with low creep properties. The grid shall be connected to low weight non-woven polypropylene fabric. The composite shall have a bitumen finish. The properties shall conform to the requirements given in Table 14-15.

Table 14-15: Properties of Asphalt Reinforcement Geogrids

Property	Unit	Test Method	Requirement		
			Tensile strength in both MD and CD, Not less than		
Tensile strength	KN/m	IS0-10319	25	50	100
% Elongation at break	%	IS0-10319	12.5%	12.5%	12.5%
Mesh Size			35×35 20×20	35×35 20×20	35×35 20×20
Melting Point	°C		>190	>190	>190

2.14.8.c Installation

2.14.8.c.1 Weather Limitations

The air and pavement temperatures shall be at least 10°C for placement of hot bitumen and at least 16°C for placement of asphalt emulsion. The asphalt tack coat or Glass grid shall not be placed when weather conditions are not suitable.

2.14.8.c.2 Surface Preparation

The pavement surface shall be dry and cleaned of all dirt and oil to the satisfaction of the Engineer. Cracks wider than 3 mm shall be cleaned and filled with suitable bituminous material appended by the Engineer. Potholes and locally failed and cracked pavement sections shall be repaired as directed by the Engineer. If the existing pavement is rough or has been milled, a levelling course shall be provided prior to installation of the Glass grid.

2.14.8.c.3 Tack Coat

The tack coat used to impregnate the fabric and bond the fabric to the pavement shall be penetration grade Bitumen of 80-100. Glass fiber grids with adhesive on one side may not require a tack coat.

The tack coat shall be applied using a calibrated distributor spray bar. Hand spraying, squeegee and brush application may be used only in locations where the distributor truck cannot reach. The tack coat shall be uniformly applied at a rate to bond the nonwoven scrim to the existing pavement surface. The tack coat application rate shall be 1 Kg per square metre or as specified in the contract. When using emulsions, the application rate must be increased as directed by the Engineer to take into account the water content in the emulsion. The temperature of the tack coat shall be sufficiently high to permit a uniform spray. Bitumen shall be sprayed at temperatures between 143°C and 163°C. For emulsions, the distributor tank temperatures shall be maintained between 55°C and 71°C. The target width of the tack coat application shall be equal to the Glass grid width plus 100-150 mm. The tack coat shall be applied only as far in advance of Glass grid installation as is appropriate to ensure a tacky surface at the time of Glass grid placement. Traffic shall not be allowed on the tack coat. Excess tack coat shall be cleaned from the pavement.

2.14.8.d Paving Fabric Placement

The paving fabric shall be placed onto the tack coat using mechanical or manual lay down equipment capable of providing a smooth installation with a minimum amount of wrinkling or folding. The paving fabric shall be placed before the tack coat cools and loses tackiness. After laying the paving fabric, some loose bituminous premix material shall be sprinkled on it in the wheel path of the paver and the tipper to ensure that the fabric is not picked up between the wheels. Paving fabric shall not be installed in areas where the bituminous overlay tapers to a thickness of less than 40 mm. Excess paving fabric which extends beyond the edge of existing pavement or areas of tack coat application shall be trimmed and removed. When bitumen emulsions are used, the emulsion shall be allowed to cure properly such that no water/moisture remains prior to placing the paving fabric. Wrinkles or folds in excess of 25 mm shall be single-lapped in the direction of the paving operation. Brooming and/ or pneumatic rolling will be required to maximize paving fabric contact with the pavement surface. Additional hand-placed tack coat may be required at laps and repairs as determined by the Engineer to satisfy bitumen retention of the lapped paving fabric. All areas where paving fabrics have been placed shall be paved the same day. No traffic except

necessary construction equipment will be allowed to drive on the paving fabric. Turning of the paver and other vehicles shall be done gradually and kept to a minimum to avoid movement and damage to the paving fabric. Abrupt starts and stops shall also be avoided. Damaged fabric shall be removed and replaced with the same type of fabric. Overlaps shall be shingle- lapped in the direction of paving. Additional tack coat shall be placed between the overlap to satisfy saturation requirements of the fabric. Overlap shall be sufficient to ensure full closure of the joint but not exceed 150 mm. Transverse joints shall be overlapped in the direction of the pavement by 100 to 150 mm or as per the manufacturer's recommendations or as directed by the Engineer. Longitudinal joints shall be overlapped by 20-30 mm or as per the manufacturer's recommendations or as directed by the engineer. The overlay operations shall be completed at the earliest after laying the fabric.

2.14.8.d.1 Glass Grid Placement

The glass grid shall be placed on the surface provided by the tack coat using mechanical or manual lay down equipment capable of providing a smooth installation with a minimum amount of wrinkling or folding. On curves, the Glass grid must be cut and realigned to match the curvature. Glass grid shall not be installed in areas where the bituminous overlay tapers to a compacted thickness of less than 40 mm. When emulsions are used, the emulsion shall be allowed to cure properly such that no water/moisture remains prior to placing the glass grid. Wrinkles severe enough to cause folds shall be slit and laid flat. Brooming and/or rubber-tire rolling will be required to maximize glass grid contact with the pavement surface. Additional hand-placed tack coat may be required at overlaps and repairs as required by the Engineer. Turning and braking of the paver and other vehicles shall be done gradually and kept to a minimum to avoid movement and damage to the glass grid. Damaged composite shall be removed and replaced with the same type of composite and a tack coat.

All areas where glass grid has been placed shall be paved the same day. No traffic except necessary construction traffic shall be allowed to drive on the glass grid. Overlaps shall be shingle - lapped in the direction of paving. Additional tack coat shall be placed between the overlap to satisfy saturation requirements of the fabric. Overlap shall be sufficient to ensure full closure of the joint but not exceeding 150 mm.

2.14.8.d.2 Overlay Placement

Bituminous overlay construction shall closely follow the placement of paving fabric or glass- grid. Excess tack coat that bleeds through the paving fabric or glass grid shall be removed by broadcasting hot mix or sand on the glass grid. Excess sand or hot mix shall be removed before beginning the paving operation. In the event of rainfall prior to the placement of the asphalt overlay, the fabric must be allowed to dry completely before the overlay is placed. Overlay asphalt thickness shall meet the requirements of the contract drawings and documents and shall be carried out in accordance with the relevant section of 3.10. The minimum compacted thickness of the first lift of overlay asphalt concrete shall not be less than 40 mm.

2.14.8.e Measurement

The paving fabric/ glass fibre geogrid shall be measured in Square metres of paved area covered by the fabric/ glass fibre geogrid. Surface preparation, tack coat and overlay shall conform to the measurement of section 3.7 and 3.10 .

2.14.8.f Rate

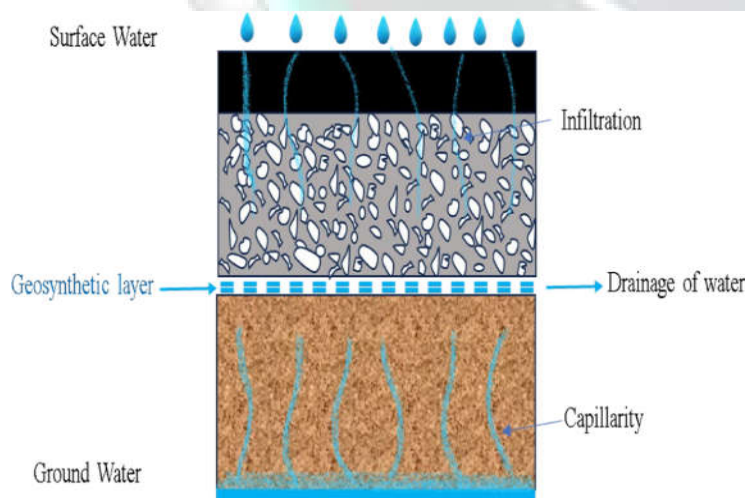
The contract unit rate shall be for the accepted quantities of paving fabric. The rate shall be full compensation for the work performed and furnishing, preparing, hauling and placing materials including all labour, material, freight, tools, equipment and incidentals to complete the work as per contract. Surface preparation, tack coat and overlay shall be paid separately according to section 3.7 and 3.10 and not included in this section .

2/14/6	Furnishing and installing Paving fabric/glass fibre geo grid (as detailed in the Drawings or as directed by the Engineer)	Square metre

2.14.9 MULTILINEAR GEO-COMPOSITE DRAINAGE

2.14.9.a Scope

Multilinear geo-composite drainage systems are engineered materials designed to manage subsurface water efficiently by combining multiple drainage elements with geotextile filters. Their scope extends across various geotechnical, civil, and environmental engineering applications where water management, slope stability, and structural integrity are critical.



Multilinear geo-composite drainage controls pore water pressure within slopes, preventing landslides and slip failures. It enhances the stability of road and railway embankments constructed over soft or moisture-sensitive soils. It is installed under or beside highway pavements to prevent water-related pavement failures such as rutting, cracking, and pumping. It relieves hydrostatic pressure behind retaining walls/ reinforced earth walls and bridge abutments.

The Contractor shall provide all necessary resources, including skilled labor, proper machine/tools, and materials to complete the scope of work for the installation of multilinear geo-composite drainage as per specification based on the approved method statement.

2.14.9.b Material Requirement

Multilinear geo-composite drainage consists of one or two filter layers (depending on project requirement), a drainage mat made of polypropylene geotextile, and a series of perforated polypropylene mini-pipes, arranged at a regular interval across the width. These components are securely bonded using a needle-punching technique.

- A needle-punched non-woven polypropylene geotextile layer (top filter).
- Polypropylene mini pipes, regularly perforated according to a 90° dual alternated axis.
- A needle-punched non-woven polypropylene capillary draining layer.
- A needle-punched non-woven polypropylene geotextile layer (bottom filter).

The needle-punching process of the elements carried out in the factory ensures excellent internal shear resistance while preserving the draining and filtering properties of each component.

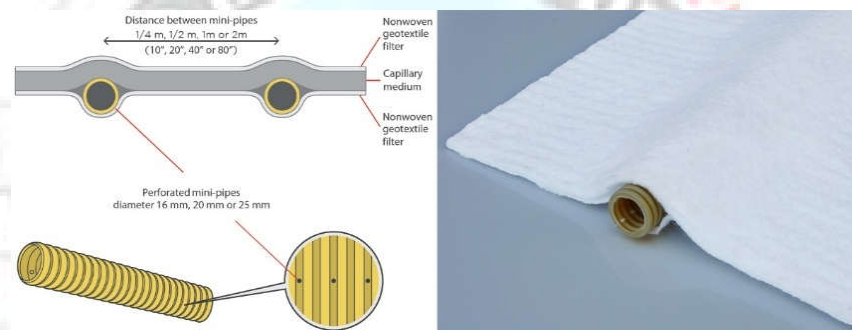


Figure 14-5: Typical section of multilinear geo-composite drain

Multilinear geo-composite drain for subsurface drainage, capillary cutoff and pumping prevention: The multilinear geo-composite drain shall meet the requirements mentioned in the following table for subsurface drainage of embankments/ slopes, capillary cutoff and pumping prevention in pavement and bank protection work, drainage blanket above vertical wick drain or PVD.

Table 14-16: Physical and hydraulic requirements of multilinear geo-composite drains having filter layers (non-woven geotextile) on both sides.

Characteristics Value	Standards	Reference	MARV*	Unit
Mechanical Characteristics				
Mass per unit area	EN ISO 9864	Geocomposite	485	g/sqm
		Geocomposite without mini-	370	
Thickness	EN 9863 -1	Under 2 kPa	4.0	mm
		Under 20 kPa	3.2	
Tensile strength	EN ISO 10319	Machine direction	14	kN/m
		Cross direction	14	
		Machine direction	60	

Tensile elongation	EN ISO 10319	Cross direction	60	%
CBR resistance	EN ISO 12236	-	2.4	kN
Mini-pipes Characteristics				
Mini-pipe Diameter	EN 61386-1	Outside diameter	19.6	mm
Pipe stiffness at 5% deflection	ASTM D 2412	-	4000	kPa
Spacing of mini-pipes	2 mini-pipes every one meter width ways			
Hydraulic Characteristics				
Apparent Opening size	ASTM D 4751	Filter layer	<200	µm
Water permeability	EN ISO 11058	Filter layer	0.070	m/s

Multilinear geo-composite drains between the embankment fills and retaining wall/ reinforced earth wall: The multilinear geo-composite drain shall meet the requirements mentioned in the following table for application between the embankment fills and retaining wall/ reinforced earth wall.

Table 14-17: Physical and hydraulic requirements of multilinear geo-composite drains having a filter layer (non-woven geotextile) on one side.

Characteristics	Standards	Reference	MARV*	Unit
Mechanical Characteristics				
Mass per unit area	EN ISO 9864	Geocomposite	326	g/sqm
		Geocomposite without mini-pipes	270	
Thickness	EN 9863 -1	Under 2 kPa	2.8	mm
		Under 20 kPa	2.0	
Tensile strength	EN ISO 10319	Machine direction	13	kN/m
		Cross direction	13	
Tensile elongation	EN ISO 10319	Machine direction	60	%
		Cross direction	60	
CBR resistance	EN ISO 12236	-	2.0	kN
Mini-pipes Characteristics				
Mini-pipe Diameter	EN 61386-1	Outside diameter	19.6	mm
Pipe stiffness at 5%	ASTM D 2412	-	4000	kPa
Spacing of mini-	1 mini-pipe every one meter widthways			
Hydraulic Characteristics				
Apparent Opening	ASTM D 4751	Filter layer	<200	µm
Water permeability	EN ISO 11058	Filter layer	0.070	m/s

2.14.9.c Installation

The Contractor shall prepare and submit method statement for the installation of multilinear geo-composite drain before the commencement of work for the approval of Engineer.

- a) Rolls of multilinear geo-composite drain shall be delivered to the job site in a manner that will not cause damage to the rolls. The rolls shall be stored flat on a smooth surface (no wooden pallets) away from dirt, mud, and excessive heat. For more detailed handling and storage information, please refer to ASTM D4873. The contractor shall handle the rolls so that they are not damaged in any way.
- b) Multilinear geo-composite drain is unrolled on a base which has been graded and compacted to the required elevation. Ensure that the product is properly oriented (Figure 14-4). Overlaps shall be done in the direction that backfilling will occur. In case of drainage on soft soil with vertical wick drains/ PVD, this is unrolled directly on the wick drains/ PVD. The hydraulic connection between wick drains/ PVD and multilinear geo-composite drain is done by simple overlap.

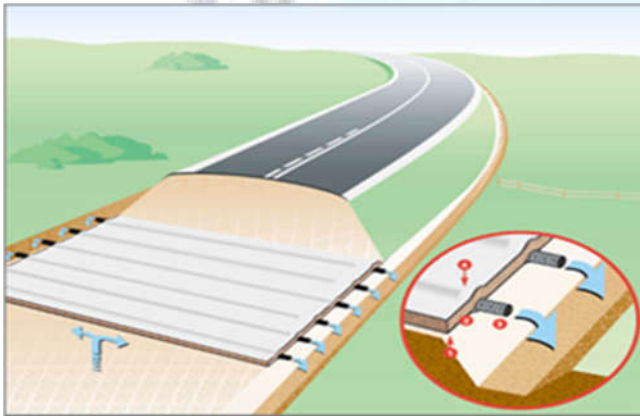


Figure 14-6: Multilinear geo-composite drain installation at embankment

- c) Connection at the leading or terminating edge of the multilinear geo-composite drain shall be overlapped such that the upper geotextile layer can be rolled back 150 mm (6 in.) minimum and the end of the next roll inserted into the opening. Mini-pipes may be either overlapped by 250 mm (10 in.) minimum or connected using snap coupler fittings supplied by the geo-composite manufacturer. Connections along the side of the roll shall be overlapped 100 mm (4 in.) minimum. Connection method requirements shall be at the engineer's discretion. Mechanical connections are recommended under high compressive loads. Overlapped geotextiles shall be secured using sewn seams, welds (hot air or flame), or additional overlap.

2.14.9.d Measurement and Payment

The multilinear geo-composite drain shall be measured in linear meters as per planned dimensions with no allowance for overlapping at joints, anchoring at toe and crest of the slope/wall/embankment. Excavation, backfill, bedding and cover material shall be measured separately as per relevant clauses of the Specifications.

The contract unit rate for the accepted quantities of multilinear geo-composite drain in place shall be in full compensation for furnishing, preparing, hauling, and placing geo-composite, including all labor, freight, tools, equipment, and incidentals to complete the work as per specifications.

Pay Item No.	Description	Unit Measurement
2/14/9/1	Multilinear geo-composite drain	Square meter

2.15 RE /MSE Wall

2.15.1 Description

The specification covers construction of reinforced soil structures together with the construction of earthwork in layers, assembly and placing of reinforcing elements and fascia elements during the construction process and all associated works. Any alternate methods proposed by the contractor shall be at the discretion of Engineer and will have to be prior approved before commencement of work.

The work shall include the design and construction of the reinforced soil structure and ground improvement measures required, if any.

The reinforced soil retaining structures can be used as, (i) Reinforced soil retaining wall, (ii) Reinforced soil abutment, (iii) Reinforced soil slope

Reinforced soil structures with a slope face angle steeper than 70° are categorized as reinforced soil walls, and those with a slope face angle less than 70° are considered as reinforced soil slopes.

The detailed design and drawings of the work shall be done in accordance with the BS: 8006:2010 “Strengthened/Reinforced Soils and Other Fills” or equivalent. The earthquake loads as per BNBC latest edition. Proprietary specifications shall be incorporated wherever relevant.

The Contractor shall determine the allowable bearing pressures and the maximum settlement of the foundation material under the RE wall using information obtained from the site-specific geotechnical investigation.

Subsurface drainage which complies with the specification shall be provided within the RE where necessary to intercept groundwater and to prevent the development of hydrostatic pressure behind the facing panels. A separate drainage system which complies with the specification shall be provided to collect and discharge surface

water into the storm water drainage system. The specific checks for the strength and service limit states required for RE wall design are listed below:

Strength Limit States for RE walls

External Stability

- Limiting Eccentricity
- Sliding
- Bearing Resistance

Internal Stability

- Tensile Resistance of Reinforcement
- Pullout Resistance of Reinforcement
- Structural Resistance of Face Elements
- Structural Resistance of Face Element Connections

Service Limit States for RE walls

External Stability

- Vertical wall movements
- Lateral wall Movements

Global Stability of RE walls

- Overall Stability
- Compound Stability

In cases where specific design details for the RE wall are not provided for a particular project, the Contractor may refer to the following guidelines. However, it's important to note that any action taken by the Engineer, including approvals, checks, certificates, consents, examinations, inspections, instructions, notices, proposals, requests, tests, or any similar acts, or the absence of disapproval, shall not exempt the Contractor from their contractual responsibilities. This includes responsibilities related to errors, omissions, discrepancies, and non-compliance with the contract terms.

The Contractor shall have in place a quality management System, which ensures compliance with the performance requirements described on the drawings and in the Specification.

2.15.2 Material

2.15.2.a Reinforcing Elements

The reinforcing element shall be metallic in the form of strips (galvanized steel strip, ladder) or mats of metal (steel grids, woven and welded steel wire meshes) or synthetic (PET, HDPE, PVA, PP) reinforcement in the form of grid or strip or strap or any other proprietary material which may be approved by the Engineer and shown on the drawings.

In case of synthetic reinforcements, there shall not be any steel component in the connection system, neither encased nor coated inside the connector, contributing to connection strength. A friction-based connection system shall not be allowed.

Carbon steel strip shall comply with BS EN 10025 / IS: 2062 or any other equivalent standard and have a silicon content of not more than 0.55 percent. The fabricated element shall be galvanized in accordance with BS 8006:2010, IS 4759 and IS 2629 or any other equivalent standard, and the minimum zinc coating weight shall not be less than 1000gm/sq.m

The steel strips with minimum bearing and shear strength of 490N/mm² shall comply with the requirements of BS EN 10025, Grade S 355 JR, or IS: 2062 grade Fe 490 or any other equivalent standard except for the elongation (on base metal) for which minimum 22% is acceptable.

The panel lugs shall be manufactured from hot-rolled steel strips with the same steel quality and grades as specified above, except that the minimum zinc coating weight not less than 600 gm/sq.m.

All permanent metallic connectors (exposed to soil), tie strips, and lugs shall be hot dip galvanized. Nuts/ bolts (fasteners) shall be galvanized as per requirements of IS: 1367-Part 3. Nuts/ bolts (fasteners) shall be grade 10.9 or any other equivalent standards.

For all metallic components, where holes or penetrations are made through the reinforcing elements to accommodate connections such as bolts, pins, or other, the cross-section thickness and / or width of metallic component shall be increased to account for section loss caused by the hole or penetration.

The manufacturer of geogrids, geotextiles, geostrips, polymeric strips or straps, polymeric ties or any other geosynthetic material, including any proprietary geosynthetic material, for use as reinforcing element shall fulfill the following requirements:

- Shall have ISO (ISO-9001), (ISO-45001) and (ISO-14001) / CE Certification/ EPD Certifications or any other equivalent certification for manufacturing process and quality control,
- The product shall have certification for use as soil reinforcing material from an agency accredited for certifying geosynthetic reinforcement products.
- The manufacturer shall provide test reports from an independent laboratory with valid accreditation, for all the tests needed to establish all the reduction factors listed below

RF_{CR} - Reduction factor for creep.

RF_{ID} - Reduction factor for installation damage

RF_W - Reduction factor for weathering

- RF_{CH} - Reduction factor for chemical/ environmental effects.
- f_s - Factor for the extrapolation of data

All the above factors shall be determined in accordance with the provisions of ISO/TR 20432- "Guide to the determination of long-term strength of geosynthetics for soil reinforcement or, any other equivalent standard.

2.15.2.b Earth Fill and Environmental Conditions

The fill in the reinforced soil zone shall have drained or effective angle of friction not less than 32°, measured in accordance with BS 8006:2010 or IS: 2720 (Part 13) or equivalent, by conducting a drained direct shear test. In case the fill material has 25 percent or more particles of 4.75 mm or larger, drained shear test using large shear box may be conducted (IS: 2720: Part 39: Section 1 or equivalent) . The gradation of fill soil shall be as per following limits.

Sieve Size	Percentage passing
75mm	100%
425 micron	0-60%
75 micron	less than 15

Materials with more than 15 percent passing 75 micron sieve, but less than 10 percent of particles smaller than 15 microns are acceptable provided PI is less than 6 and angle of friction is not less than 32°.

Fly ash may be used as fill material in reinforced soil walls provided its angle of internal friction is not less than 32 degree and PI is less than 6. Gradation requirements need not be completely satisfied. Reference may be made to IRC or equivalent Guidelines on Use of Flyash in Road Embankments (IRC SP-58 or equivalent). Fly ash shall also satisfy requirements concerning pH and environmental conditions of the fill vis-à-vis the reinforcement type as specified in specific clause of the specification.

The fill material used in the reinforced soil zone shall be free from organic or other deleterious materials and shall not react adversely (chemically, electrically or biologically) with the reinforcement material and / or facia material.

Properties of fill soil in the reinforced zone, unreinforced zone (or retained/back fill) soil and the foundation soil shall be determined accurately during the construction phase, as per quality assurance plans and directions of Engineer so as to ensure that these are the same as those considered in the design phase.

The fill soil in the unreinforced zone shall conform to the requirements specified in the design.

Where galvanized steel reinforcement is used, the fill material shall be free draining granular material and shall meet the following requirements as per table below

Table 15-1. Recommended Limits of Electrochemical Properties for Reinforced Fills with Steel Reinforcement

Property	Criteria	Test Method
Resistivity	> 3000 ohm-cm	AASHTO T-288 or equivalent
pH	> 5 and < 10	AASHTO T-289 or equivalent
Chlorides	< 100 PPM	ASTM D 4327 or equivalent
Sulphates	< 200 PPM	ASTM D 4327 or equivalent

2.15.2.c Facing Material

The facing system shall be one of the following

- Precast reinforced concrete panels
- Precast concrete blocks and precast concrete hollow blocks.
- Gabion facing
- Wrap around facing using geosynthetics
- Metallic facing, prefabricated in different shapes including welded wire grid and woven steel wire mesh
- Other proprietary and proven systems

Facing shall be sufficiently flexible to withstand any deformation of the fill and foundations. The facia units to be adopted in the project shall be shown in the drawings and shall be approved by the Engineer.

Facia type adopted shall be given in the design and shown with complete details in the drawings. The system supplier shall provide any test data to satisfy the Engineer regarding the properties and suitability of the facia system adopted, if so required.

Where facia such as wrap around or mechanically woven gabion or welded wire and woven steel wire mesh facings have been used and where climate conditions are appropriate, a green finish shall be provided where specified.

Connection between the facia panels and the reinforcing element shall be by using either nut or bolt, HDPE inserts with bodkin joint, hollow embedded devices, polymeric/ steel strips/rods/pipes, fibre glass dowels or any other material shown in the drawings. Connection relying on steel bar should be avoided as the steel bar may get corroded and impact the durability of the structure. The connection between the panel and the reinforcement shall provide for 100 % of the long term design strength of the reinforcing element in continuity.

In case of modular block facia and other type of facia such as gabion facia, where the

reinforcement is held by friction between the fascia block and the reinforcement, the results of pullout test as per ASTM D 6638 “Standard Method of Test for Determining Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units” shall prevail. The hollow concrete blocks must have mechanical connection and friction-based connection shall not be allowed.

The available connection strength shall satisfy the design requirements and shall not be less than the maximum possible tensile force that the reinforcement layer under consideration may be subjected to. Connection test report shall be submitted prior to construction.

The connection strength shall be derived based on third party test conducted on all types of facing panels (as per the proposed shape). The third-party test reports shall be produced for all types of connections. No other mechanical connection system where the connection strength cannot be justified by laboratory testing shall be allowed.

The connection test methodology shall be as follows;

The design connection strength values shall be established based on connection pullout test results. To estimate the realistic panel connection strength values, the field pullout testing on the actual panels shall be tested. The connection strength testing method shall be carried out on a horizontal bed. The test panel can be placed in an open pit excavated below ground level or beam arrangement on a level ground to accommodation soil cover over the panel. The sand is placed layer by layer and compacted to the required thickness.



Fig 15-1: Typical Panel Connection Testing Setup

The steel loading frame is placed over the compacted fill at the centroid of the connectors symmetrically. The hydraulic jacks and the associated accessories should be assembled as shown in Figure above. The load is applied gradually till the failure.

2.15.4 Construction Methods

2.15.4.a Depth of Foundation

A strip footing, minimum 350mm wide and 150mm thick in 15Mpa grade plain concrete, shall be provided at founding level to receive the facia or the bottom most reinforcement.

The depth of embedment below the finished ground level at the foot of the wall shall not be less than 1000 mm. In case rock is met above founding level, the depth of embedment shall be adjusted as per ground conditions.

2.15.4.b Concrete Quality and Strength

Panels shall be made of vibrated concrete with the following requirements:

Characteristic compressive strength at 28 days	Minimum 30 MPa
Maximum aggregate size	20 mm
Maximum free water/cement rat	0.45

For sea walls or structures facing severe exposure conditions, thicker panels with higher cement (Sulphate resistant cement) content shall be specifically designed for the intended purpose. Reinforcing element should be polyvinyl alcohol (PVA) coated synthetic strips.

2.15.4.c Laying of Reinforcement

The reinforcing elements shall be placed at right angles to the face of the wall or design axis, with greater cross-sectional dimension in the horizontal plane and the length shall be as shown in the drawings. Reinforcing elements such as geogrids, shall be stretched and held taut by driving nails or pegs at the farther end. Reinforcing element as such as geostrips, shall be laid in V shape fashion from face to rear end.

2.15.4.d Facing Batter

It may be necessary to set facing unit at an additional batter than as provided in the drawings since there is a tendency for initially positioned units of facia to lean outward as the fill material is placed and compacted. Care and caution shall be taken to accommodate this phenomenon. At the end of the construction, the face may have a slight residual inward batter.

2.15.4.e Drainage

Drainage bay shall be provided. The width of the drainage bay shall be 600 mm behind the facing element. The drainage material shall conform to the specifications of the filter media as outlined below:

- Filter design may not be required if embankment consists of CH or CL soils with liquid limit greater than 30, resistant to surface erosion. In this case, if a layer of material is used as bedding for pitching, it shall be well graded and its D 85 size shall be at least twice the maximum void size in pitching
- In the foregoing, D 15 means the size of that sieve which allows 15 percent by weight of the filter material to pass through it and similar is the meaning of D 50 and D 85 (15 being replaced with 50 and 85 respectively).
- If more than one filter layer is required, the same requirement as above shall be followed for each layer. The finer filter shall be considered as base material for selection of coarser filter.
- The filter shall be compacted to a firm condition. The thickness of filter is generally of the order of 200 mm to 300 mm. Where filter is provided in two layers, thickness of each layer shall be 150 mm

Alternatively, the multilinear geo-composite drain of specifications mentioned as per Clause of RHD specifications (2.14.9) shall be adopted.

2.15.4.f Laying and Compaction

The reinforcing elements shall be laid free from all kinks, damage and displacement during placing, spreading, levelling and compaction of the fill. The programme of filling shall be such that no construction plant moves directly on the reinforcement.

All construction plant having a mass exceeding 1500 kg shall be kept at least 2.0m away from the face of slope or wall.

In the area up to 2.0 m from the face of slope or wall, the following compaction plant shall be used:

- Vibratory roller having a weight per meter width not exceeding 1300 kg with total weight not exceeding 1500 kg
- Vibratory plate compactor of maximum weight 1000 kg
- Vibro tamper having a weight not exceeding 75 kg

Before allowing the movement of vehicles over the reinforcement, a minimum compacted thickness of 150mm shall be provided over the reinforcement and the speed of the vehicles shall be restricted to 10 km/hr.

During construction of reinforced fill, the retained material beyond the reinforcement at the rear of the structure shall be maintained at the same level as reinforced fill.

Fill shall not be placed on surface that contains mud, organic soil or area that have not met compaction requirement.

The thickness of compacted layer shall not be more than 200 mm, compacted to at least 95 per cent of maximum laboratory density.

(vi) Construction Serviceability and Tolerances

The construction tolerances shall be as per the following:

Casting of pre-cast RCC panels: All elements shall be manufactured within the following tolerances:

- All dimensions within ± 5 mm
- Evenness of the front face: ± 5 mm over 1500mm
- Difference between lengths of two diagonals: 5mm max.
- Thickness: + 5 mm (-) 0 mm

Description	Tolerance
Location of plane of structure	± 50 mm – metallic reinforcement ± 75 mm – synthetic reinforcement
Bulging (Vertical) and Bowing (Horizontal)	± 20 mm in 4.5 m template (Metallic) ± 30 mm in 4.5 m template (Synthetic)
Steps at joints	± 10 mm

Dimensions of modular concrete blocks shall not differ more than ± 2.5 mm for length and width and ± 1.5 mm in height. Minimum vertical movement capacities required for facing systems to cope with vertical internal settlement of reinforced fill shall be as below:

Structural form	Minimum vertical movement capacity of system	Differential settlement from EN 14475 or equivalent	Alignment from EN 14475 or equivalent
Discrete panels	Joint closure of 1 in 150 relative to panel height	$\sim 1\%$ with panel aspect ratio ≈ 1 to $\sim 0.5\%$ with larger ratios.	± 25 mm
Full height panels	Vertical movement capacity of connections 1 in 150 relative to panel height	$\leq 0.5\%$	± 25 mm
Concrete blocks		$\sim 0.5\%$	± 50 mm

Semi-elliptical facings	Vertical distortion of 1 in 150 relative to panel height	~ 2%	± 100mm
Geotextile/Geogrid wrap-around facings	No specific limit except for appearance or serviceability considerations	~ 2%	± 100mm
Gabion facings	No specific limit except for appearance or serviceability considerations	~ 2%	± 100mm

2.15.5 Measurement and Payment

The unit of measurement for furnishing and fabricating the materials for the RE walls, including concrete facing panels, leveling pad, soil reinforcements, attachment devices, connectors, fasteners, bearing pad and shims, supply and installation of specified drainage bay/ multilinear geo-composite material, joint materials and incidentals shall be the square meter of wall surface area. The wall surface area shall include the surface area of nominal panel joint openings and wall penetrations such as pipes and other utilities. The quantity to be paid for shall be measured on the basis of wall surface area supplied.

The rate shall include full compensation for the design and drawing of the RE wall.

The rate shall exclude the cost of investigations, design and construction of ground improvement measures. Measurement for friction slab and crash barrier shall be separately and in linear meter.

Pay Item shall be:

Pay Item No.	Description	Unit Measurement
2/15/1	Reinforced Earth Wall	Square Meter
2/15/2	Supply and laying of Reinforced Earth fill at the reinforced zone as per drawing and specifications.	Cubic Meter
2/15/3	Supply and laying of Embankment fill at the unreinforced zone as per drawing and specifications.	Cubic Meter

2/16/4	Excavation upto the depth of the embedment.	Cubic Meter
2/16/5	Crush Barriers and Friction Slabs	Metre

2.16 STABILIZATION OF SLOPE

2.16.1 Description

This work shall consist of the stabilization of the slope using the Soil Nail technique. Soil Nail is an in-situ soil reinforcement technique, which is a method for stabilization and retaining of existing slope/structure by inserting fully threaded solid galvanized steel (minimum average zinc coating thickness shall be 70 microns), hot rolled/ mill threaded geotechnical bars (Yield strength $\geq$ 670Mpa and Ultimate tensile strength $\geq$ 800Mpa) inside an unstable or potentially unstable slope at a define spacing and length to form a gravity retaining structure within the existing soil slope itself.

2.16.2 Soil Nail Behaviour and Design Concepts

The design concept is to reinforce and strengthen the unstable slopes by in-situ installation of Soil Nail. Soil Nail creates a reinforced soil mass that is internally stable and able to retain the ground mass within the unstable slope against active pressure, slip circle failure and global stability. Soil Nail are designed to cater the tensile force generated within nail material and pull-out resistance.

The detailed design and drawings of the work shall be done meeting the ultimate and serviceability limit state requirements as per French Standard AFNOR NF P 94-270, July 2009 “Geotechnical design of Retaining Structures reinforced fill and soil nailing structures” or in accordance to BS: 8006:1995 “Strengthened/Reinforced Soils and Other Fills” where ever relevant. Reference can be made to FHWA-NHI-14-007, “Soil nail walls reference manual”, February 2015 OR FHWA-SA-93-026, “Recommendations Clouterre, 1991 by French National Research Project Clouterre” regarding soil nailing construction and installation guidelines or equivalent code. Specialized system supplier’s Specifications shall also be incorporated wherever relevant for design and construction.

2.16.3 Scope of Work

2.16.3.a General

Slope stabilization using Soil Nail is a specialized work. The Contractor shall make his own arrangements to secure the design, supplies and technical services needed from one specialized technology provider. The work consists of designing and constructing permanent Soil Nail stabilized slope through specialized technology providers. The contractor shall arrange all design calculations, drawings, materials to retain and construct the Soil Nail slope in accordance with this specification through one specialized technology provider.

The work shall consist of grouted and galvanized fully hot threaded solid soil nails described elsewhere in this document. Other soil nails, like solid cold threaded re-bars/ strands/ driven nails of any type are not allowed in this work.

2.16.3.b Slope Stability Analysis

The slope stability shall specifically be checked for global/Local slip failures using TALREN | SLIDE 2.0 design software (Advanced stability software in geo techniques) or equivalent prior to commencement of all works.

2.16.3.c Drilling

To ensure good performance and high pull-out strength of Soil Nail, the hole has to be drilled and grouted immediately after drilling and to ensure effective length of the drilled hole just before grouting, an additional drilled length of 0.25m to 0.5 m to the design nail length should be drilled to ensure the availability of minimum design length irrespective of presence of debris towards the bottom of the hole. However, the nail length should remain same as per the design length. There are many drilling techniques and tools that can be adopted for drilling holes; however, for this project only drilled and grouted method shall be adopted, which is the most commonly used method worldwide for permanent stability. Basic requirements of proper or efficient drilling for Soil Nail are deployment of suitable machines (appropriate combination of thrust, torque, rotary speed, percussive force and flushing methods) and skilled operator to ensure high quality installation and timely completion of the project. While carrying out the drilling, following points must be ensured.

- The drill diameter shall be as shown on detailed design and approved construction drawing. Complete the drilling as soon as possible (typically less than 1 hour for the specified nail geometry).
- Machines shall be capable of permitting continuous and straight penetration in material that may invariably change abruptly from some localized soft to extremely, hard or rock strata, etc.
- The equipments used must be capable of providing a constant diameter, stable drilled hole, wholly and cleanly removing the debris.
- Soil Nail holes (drill holes) are drilled using one of several available drilling methods, including rotary, percussion, auger, and rotary/percussion drilling. Rotary percussive drilling method using suitable top hammer or down the hole (DTH) hammer with proper drill bits (75mm to 300mm) to suit the types of materials can meet the above requirements.

2.16.3.d Soil Nail Reinforcement

The main function of Soil Nail reinforcement is to transfer load by tension when the whole nail lengths are bonded to the soil. Soil Nail reinforcements shall be mill/hot threaded (fully threaded i.e. threaded in full length) solid hot-dip galvanized with epoxy-coated geotechnical bars. The length of the bar shall be kept not more than 7.0m. The hot-dip galvanization shall conform to IS 4759: 1996 requirements, except that the average zinc



Fig 16-1: Soil Nail Assembly Details

coating weight on the outer surface is not less than 500gm/m² (equivalent thickness of 70 microns). If the required length of Soil Nail reinforcement is more than one single bar, then the bars can be joined together using couplers. The detailed specification is as follows:

Nominal Diameter (mm)	Grade (MPa)	Weight (kg/m)	Cross Section (mm ²)	Yield Load (kN)	Ultimate Load (kN)	Elongation min. (%)
25	670/800	3.85	491	329	393	5
28	670/800	4.83	615.8	412.7	492	5

The Soil Nail shall be free from dirt and soil. Excessive force shall not be allowed in inserting the Soil Nail. In case of insertion refusal, the nail shall be withdrawn and reinserted after re-drilling the drilled hole.

2.16.3.e Bar Coupler

Bar coupler if required, shall develop full ultimate tensile strength of the bar as certified by the manufacturer.

2.16.3.f Nail Grout

Grouting with a neat cement grout with non-shrink admixture or flyash/sand/cement mixture (with a minimum 3-day compressive strength of 10.5 Mpa and a minimum 28-day compressive strength of 21 Mpa) is used to fill up the voids in the drilled hole. This strengthens the ground immediately adjacent to the drilled hole, enhances the bond strength and protects the bar against the corrosion. Grouting shall be carried out simultaneously with drilling and insertion of Soil Nail, unless otherwise approved by the Engineer as per the local working condition. If in any case grouting is done afterwards, then drilled hole left overnight for a longtime un-grouted may encounter excessive swelling or relaxations and loss of bond strength. Also drilled holes left for days and have been subjected to wetting by inflow surface runoff can lose bond strength by more than 50%. In such case the drilled hole shall be protected with PVC pipe or for drilled hole that have been left un-grouted for too long or left overnight should be re-drilled (larger by 15% and longer and flushed clean again by compressed air just before grouting. In specific case, pressure grouting before insertion of nail is acceptable provided that the Soil Nail is immediately inserted through the grout without difficulty and the bond strength is confirmed by pull-out test.

2.16.3.g Drainage

100 mm dia. (nominal) semi-perforated PVC pipes wrapped with non-woven Geotextile shall be inserted (wherein applicable) within the unstable slope by drilling method. The length shall be as per designer's recommendation and as shown on the approved drawings. This will release the pore water pressure, which may develop within soil mass. Detailed drainage arrangement shall be made as shown in the construction drawing.

2.16.4 Construction

2.16.4.a Excavate Initial Cut (if relevant)

Before commencing excavation, all surface water above the face to be nailed must be controlled by the use of collector trenches to intercept and divert surface water. The initial cut is excavated to a depth slightly below the second row of nails, typically about 1 to 3 meters depending on the ability of the soil to stand unsupported for a minimum period of 24 to 48 hours. This may require either a closer spacing of the two top rows of Soil Nail or to increase the downward inclination of the first row of Soil Nail by 5° to encounter a better bond zone. Where face stability is problematical for these periods of time, a stabilizing berm can be left in place until the nail has been installed and final trimming then takes place just prior to application of the facing. Mass excavation is done with conventional earth moving equipment. Final trimming of the excavation face is typically done with a non-toothed backhoe or hydraulic excavator bucket or manually. Usually, the exposed length of the cut is dictated by the area of face that can be temporarily stabilized in the course of a working shift. The excavated face profile should be reasonably smooth and regular. A level working bench on the order of 5 to 10 meters width is typically left in place to accommodate the drilling equipment used for nail installation. Smaller tracked drills are available that can work on bench widths as narrow as 3 meters and with headroom clearance as low as 4 meters. Steepening of existing slopes by inserting Soil Nail may require the drilled bed to be mounted on an excavator arm and slave powered from the drill rig due to the lack of adequate bench width. Excavations shall be in accordance with the requirements of General and Special Specifications and in reasonably close conformity to the limits and construction stages shown on the drawings.

2.16.4.b Drill Hole for Soil Nail

Nail holes are drilled at predetermined locations to a specified length and inclination using a drilling method appropriate for the ground conditions. Drilling methods include both uncased methods for more competent materials (rotary or rotary percussive methods using air flush, and dry auger methods) and cased methods for less stable ground (single tube and duplex rotary methods with air or water flush, and hollow stem auger methods).

2.16.4.c Install and Grout Nail

In case the soil is non-collapsible in nature, drilling is done first and then the Soil Nail of required length is inserted and grouted immediately to avoid any possible collapse.

In case the soil within the slope is collapsible in nature, a drill bit is screwed on the first bar. Then the bar is directly connected to the shank of the drilling machine (with a grout injection box if necessary). The drilling operation starts together with the injection of the grout in the Soil Nail. The cement grout flows in the ground through injection hole of the drill bit. When the first Soil Nail is fully inserted in the ground, the injection is stopped as well as the drilling, and the bar is unscrewed from the shank. A second Soil Nail is connected both to the first one by means of coupler and to the shank, then the process of drilling and grouting starts again until the nail is fully inserted in the soil. Or casing with solid Soil Nail bar shall be used.

2.16.4.d Facing on the Slope Surface

High Strength Welded Mesh: The meshes are galvanized steel welded mesh units. The units are joined vertically using 200mm overlap and horizontally using 4mm dia. spiral ring. The steel mesh shall be made from hard drawn steel wire having minimum diameter of 6mm (yield strength $\geq 350\text{Mpa}$, ultimate tensile strength $\geq 450\text{Mpa}$ and elongation $\geq 10\%$) and grade B500B or B550C complying with EN10080 or alternatively SAE1010/1019, galvanization shall be done as per

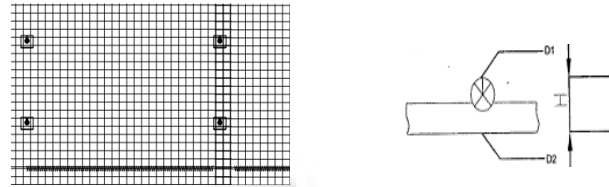


Fig 16-2: welding details

IS2629:1985 except the zinc coating which shall be minimum 500 grams per sqm. The welding joint of the mesh shall have minimum interpenetration of 8% of the total diameter of the welded bar. Total height of the welded bars $H \leq (1-0.08) \times (D1+D2)$.

Only hot-dip galvanized welded steel mesh facing made of minimum 6mm diameter bar shall be allowed to be used. PVC coated and/or galvanized double twisted meshes having lower specification compared to the above shall not be accepted in this project.

2.16.4.e Erosion Control Coir Blanket

One layer of biodegradable erosion control blanket in the form of coir geotextile shall be laid and fixed below the facing mesh. Biodegradable erosion control mattress is a mechanically bonded erosion control blanket made from bio-degradable non-woven coconut fiber reinforced with closely woven very fine HDPE nets on both sides of the mattress having polymeric net on both sides. The detailed specification of the erosion control mat shall be as under;

Property	Test Method	Unit	Value
Thickness	ASTM D6525	mm	7.5
Mass	ASTM D5261	g/m ²	600
Tensile Strength (Machine direction)	ASTM D6818	kN/m	8.0
Tensile Strength (Cross Machine direction)	ASTM D6818	kN/m	4.0
Elongation at max (Machine direction)	ASTM D6818	%	48
Elongation at max (Cross Machine direction)	ASTM D6818	%	50
CBR Puncture Strength	ASTM D6241	KN	1.35

Netting (HDPE, Light Weight)	All over both sides
Matrix (100% Coconut Fiber)	600 g/m2

Hydro seeding and watering shall be done to support vegetation growth on the slope surface as per the climatic condition of the project site.



Fig 16-3 : Typical view of stabilized slope and vegetation

2.16.5 Measurement and Payment

Pay Item No.	Description	Unit Measurement
2/16/1	Earth work in excavation by mechanical means (Hydraulic excavator)/manual means over areas including getting out and disposal of excavated earth lead as directed by Engineer-in-charge.	Cubic meter
2/16/2	Soil Nail for Slope Stabilization: Design, providing construction drawings, providing methodology and supply of fully threaded hot rolled (mill threaded), hot-dip galvanized solid geotechnical bars as Soil Nail (galvanization minimum 500 grams per sqm) of required diameter, having yield strength $\geq 670\text{N/mm}^2$ and ultimate tensile strength $\geq 800\text{N/mm}^2$. This rate includes supply of nut, bearing plate, coupler, centralizer, cost of drilling, installation of soil nails and grouting using appropriate machine, manpower, tools, tackles, fuel all complete system assembly as per approved drawing and detailed technical specification.	
2/16/2a	25mm diameter of Soil Nail	Running meter
2/16/2b	28mm diameter of Soil Nail	Running meter
2/16/3	Surface protection works for excavated slope using hot-dip galvanized prefabricated welded steel mesh:	Square meter

	Supply and installation of prefabricated flexible galvanized steel mesh of 100mm X 100mm aperture size, made from minimum 6mm dia. bars having minimum galvanization of 500 grams/sqm, welded in such a way that the welding joints of the mesh shall have minimum interpenetration of 8% of the total diameter of the welded bar and having 200mm overlap on vertical joints and horizontal panels jointed using the spiral ring of 4mm dia. including appropriate machine, manpower, tools, tackles, fuel, laying of erosion control coir blanket, local seed with humus for vegetation/hydro seeding all complete as per the drawing and detailed technical specification.	
2/16/4	Supply of OPC 52.5 grade cement for the grout mix (50 Kg)	Bags
2/16/5	Supply of non-shrink grout.	Kg
2/16/6	Supply and installation of 100mm dia. (nominal) semi-perforated PVC pipe wrapped with non-woven geotextile to drain out sub-surface water as per approved drawing and detailed technical specification including, manpower, machinery, tools, tackles, all complete.	Running meter

2.17 REINFORCED SOIL STEEPED SLOPE OR REINFORCED SOIL HYBRID/COMPOSITE STRUCTURE

2.17.1 Description

This work shall consist of Reinforced Soil steep slopes comprising of construction of internally stabilized soil mass, built in layers, duly compacted with specific fill requirements with top three layers of 50mm wide High Adherence Polymeric/ Geosynthetic strap and 50mm wide Standard Polymeric/ Geosynthetic strap coated with Linear Low-Density Polyethylene (LLDPE) as soil reinforcing structural elements of designated grades and design strengths connected directly with flexible galvanized steel mesh facing through mechanical connection system.

Design and construction of Reinforced Soil steep slope shall include all dead and live loads and combinations, seismic loads, drainage provision for dissipation of pore water pressure and flexible galvanized steel mesh facing system with erosion protection measure for long-term performance. The contractor shall assess and substantiate the availability and design adequacy of foundation soil for overall stability under the location of the Reinforced Soil steep slope before execution of the works.

The detailed design and drawings of the work done in accordance with BS:8006:2010, “Strengthened/Reinforced Soils and Other Fills,” meeting the ultimate and serviceability limit state requirements as per other international standards wherever relevant.

In case of Reinforced Soil Hybrid structures, the detailed design and drawings of the work shall be done meeting the ultimate and serviceability limit state requirements as per FHWA0-IF-03-017, “Geotechnical Engineering Circular No.7 on Soil Nail Walls”, March 2003 OR in accordance to BS: 8006:2010 “Strengthened/Reinforced Soils and Other Fills” wherever relevant. Reference can be made to the design method as per French Standard AFNOR NF P 94-270, July 2009, “Geotechnical design of Retaining Structures reinforced fill and Soil Nailed structures” regarding Soil Nail construction and installation guidelines.

Reinforced Soil Hybrid System without any mechanical connection shall not be acceptable. Also, any other soil reinforcement in the form of grid/ mat/ sheet/ tendon made of metal or geosynthetic or any other materials shall not be acceptable.

2.17.2 Scope of Works

In case there is a scarcity of space to lay the soil reinforcing geosynthetic strap in Reinforced Soil Structure, then soil nail (Grade 670/800) as specified above (General Specifications 2.17) shall be used to form a composite or hybrid Reinforced Soil structure. In such case, the soil nail shall be positively/ actively connected with the soil reinforcing geosynthetic strap of the reinforced soil retaining structure by using a mechanical connection comprising galvanized steel hooks and an encapsulated polyester loop having rotational flexibility on horizontal and vertical planes. The connection system shall have connection strength of 100kN per connection of geosynthetic strap soil reinforcement.

2.17.3 Construction

2.17.3.a Levelling Pad

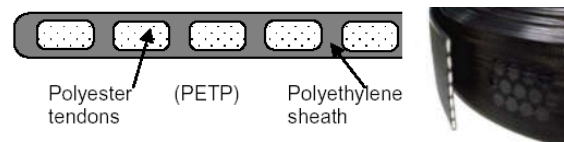
A PCC levelling pad (minimum 350mm wide and 150mm thick) shall be provided under the walls as a seat beam just to rest the facing panel on a levelled surface. Concrete shall have a grade either C-15 or equivalent. The maximum size of aggregates shall be 20 mm. The pad shall be cured for at least 05 days prior to placing panels. The top surface shall be levelled at ± 3 mm tolerance.

2.17.3.b Soil Reinforcement

A combination of the following soil reinforcement shall be used in the construction of the Reinforced Soil structure, depending upon the structure geometry and design.

a. Geosynthetic strap:

The geosynthetic strap shall be 50 mm wide with smooth edges. Geosynthetic strap consists of discrete channels of closely packed high tenacity polyester tendons encased in a Linear Low-Density Polyethylene sheath (LLDPE).



b. High Adherence (HA) Geosynthetic strap:

High Adherence (HA) Geosynthetic strap is 50 mm wide with trapezoidal groove-like rib (lateral teeth) on both sides of the strap to generate high friction. It consists of discrete channels of closely packed high tenacity polyester tendons encased in a Linear Low-Density Polyethylene sheath (LLDPE). Top layers of soil reinforcement require a high coefficient of apparent friction, and the minimum coefficient of apparent friction at the top-most layer shall be 1.5. Hence, HA straps shall be used in the top three layers of the structure to generate superior frictional resistance. The rest of all layers of soil reinforcement shall be with a 50mm wide Geosynthetic strap having a smooth edge, depending upon the detailed design of the structure.



Table 17-1: Geosynthetic strap reinforcement: Reinforcement specification

Type	Geosynthetic strap and High Adherence (HA) Geosynthetic strap									
Grade	25	30	37.5	40	50	60	70	80	90	100
Nominal Width (mm)	49.5									
Tolerance	+/- 0.5									
Characteristic Strength (kN)	25	30	37.5	40	50	60	70	80	90	100

The geosynthetic strap must have the following certification:

- CE certification.
- EPD declaration.
- The manufacturing factory must be ISO 9001, ISO 14001 and ISO 45001 certified.

2.17.3.c Facing of Steep Slope

In Reinforced Soil steep slope structures, the facing units are galvanized steel welded mesh units. The steel mesh shall be of either 'I' shape or 'L' shape, depending upon the slope angle. Special compressible type galvanized steel mesh panels and secondary reinforcement may be used for total wall | slope height more than 15.0m to allow enhanced flexibility in the wall | slope, as per recommendation and design of a specialized system | technology provider.

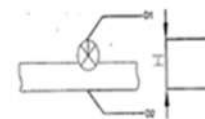


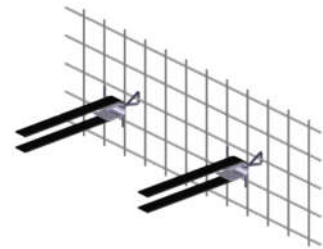
Fig 16-4: welding details

The steel mesh shall be made from hard drawn steel wire having minimum diameter of 8mm (yield strength $\geq 350\text{Mpa}$, ultimate tensile strength $\geq 450\text{Mpa}$ and elongation $\geq 10\%$) and grade B500B or B550C complying with EN10080 or alternatively SAE1010/1019, galvanization shall be done as per IS2629:1985 except the zinc coating which shall be minimum 500 grams per sqm. The welding joint

of the wire shall be interpenetration between 12% to 15% of the total diameter of the welded wire. Total height of the welded bars $H \leq (1-0.12) \times (D1+D2)$.

2.17.3.d Mechanical Connection System

The connection system between the soil reinforcement and Reinforced Soil Wall facing shall be direct and active/ positive in nature, as shown as per the recommendation of BS:8006 for high seismic zones. The connection shall consist of galvanized steel mid steel loops, hooks, and a horse-shoe plate. The weight of galvanization shall not be less than 610 grams per sqm.



In case of Reinforced Soil Hybrid structure, Active/ Positive connection shall also be used between the soil reinforcing element and Soil Nail of the slope to ensure proper transfer of loads between the soil nailed slope and Reinforced soil structure. Such connectors shall have rotational flexibility in both horizontal and vertical plane. It will be ensured that there shall not be a point load on the soil reinforcing strap at the connection location between the Soil Nail and Geosynthetic Strap.

Minimum connection strength between facing and Geosynthetic Strap soil reinforcement shall be 50kN, and minimum connection strength between Geosynthetic Strap soil reinforcement and Soil Nail shall be 100kN.

2.17.3.e Fill Materials

2.17.3.e.1 Principal fill material:

The properties of structure fill, subsoil and the retained fill and their interface media shall be based on assumed representative soil data at the design stage, but the values shall be verified at the time of the construction. Fill in the wall shall be well graded wholly frictional non-cohesive free draining material. Stratified layers of combined frictional and cohesive-frictional fill shall not be used without specific design check.

The angle of internal friction of the reinforced and retained fill shall not be less than 32° respectively. The design shall be done considering the actual properties of the fill material subject to conformity of the above minimum value. Backfill materials used in the Reinforced Soil volume shall be reasonably free from organic or otherwise deleterious materials and shall conform to the following mechanical requirements. The plasticity index (PI) shall be less than 6 and co-efficient of uniformity (Cu) shall be greater than 2

Mechanical requirements:

Sieve size	Percent passing
80 mm (gravel)	100%
4.75 mm (coarse sand)	more than 75%
75 micron (silt)	less than 15%

2.17.3.e.2 Laying and compaction:

Backfill placement shall follow closely the erection of each lift of Reinforced Soil steel mesh panels. At each reinforcing Polymeric strap level, backfill should be roughly leveled before placing and connecting the Polymeric strap. Reinforcing Polymeric strap shall be placed normal to the face of the structure or as shown on the drawings. The maximum layer thickness shall not exceed 200 mm. The Contractor shall decrease this thickness if that is necessary to obtain the specified density.

At the end of each day's operation, the contractor shall shape the last level of backfill as to permit runoff of rainwater away from the structure face. Backfill shall be compacted in accordance to the project specifications for embankment to a minimum required compaction of 95% in the entire width of the embankment, except up to 1.5m from the rear face of the structure, where the required compaction shall be minimum 90% of maximum density and shall be determined by the standard test and that the moisture content shall be plus or minus 2% of the Optimum Moisture Content as determined. Backfill compaction shall be accomplished without disturbance or distortion of the reinforcing Polymeric strap and Reinforced Soil steel mesh panels. Compaction in a strip of 1.5 meters width adjacent to the backside of the Reinforced Soil steel mesh facing shall be achieved using a manually operated vibrating plate compactor, such that adverse edge stresses are not transferred to the facing panels during construction.

2.17.3.e.3 Fill material in face of construction:

Vegetation Facing: A special fill material must be used at the front of the construction, i.e., behind the facing mesh, over a width of approx. 300mm for the growth of vegetation. This material must be of fine grain and feature good water retaining properties, apart from having some organic content. This soil shall be filled inside synthetic bags, and the bags shall be placed behind the steel mesh facing. One layer of non-woven geotextile filter shall be placed between the soil bags and the primary fill materials so that the fines from the reinforced zone do not pass through. A layer of non-woven coir geotextile shall be used for better retention of water on the slope. The coir geotextile shall conform to the following properties as minimum requirement:

Property	Test Method	Unit	Value
Thickness	ASTM D6525	mm	7.5
Mass	ASTM D5261	g/m ²	600
Tensile Strength (Machine direction)	ASTM D6818	kN/m	8.0
Tensile Strength (Cross Machine direction)	ASTM D6818	kN/m	4.0
Elongation at max (Machine direction)	ASTM D6818	%	48
Elongation at max (Cross Machine direction)	ASTM D6818	%	50

CBR Puncture Strength	ASTM D6241	KN	1.35
Netting (HDPE, Light Weight)	All over both sides		
Matrix (100% Coconut Fiber)	600 g/m2		

2.17.3.f Sub-Surface Drainage

Drainage shall be very strictly followed as per the drawing and specifications in detail. Multi-linear geo-composite drainage composed with filter layer, a drainage mat, and mini-pipes shall be used as horizontal drainage gallery and chimney drain per the following detailed specification:

Characteristics Value	Standards	Reference	MARV*	Unit
Mechanical Characteristics				
Mass per unit area	EN ISO 9864	Geocomposite	425	g/sqm
		Geocomposite without mini-pipes	370	
Thickness	EN 9863 -1	Under 2 kPa	4.0	mm
		Under 20 kPa	3.2	
Tensile strength	EN ISO 10319	Machine direction	14	kN/m
		Cross direction	14	
Tensile elongation	EN ISO 10319	Machine direction	60	%
		Cross direction	60	
CBR resistance	EN ISO 12236	-	2.4	kN
Mini-pipes Characteristics				
Mini-pipe Diameter	EN 61386-1	Outside diameter	19.6	mm
Pipe stiffness at 5% deflection	ASTM D 2412	-	4000	kPa
Spacing of mini-pipes	1 mini-pipe every one meter widthways			
Hydraulic Characteristics				
Apparent Opening size	ASTM D 4751	Filter layer	<200	µm
Water permeability	EN ISO 11058	Filter layer	0.070	m/s

MARV*= Minimum Average Roll Value

2.17.4 Measurement and Payment

Pay Item No.	Description	Unit Measurement
2/17/1	Earth work in excavation by mechanical means (Hydraulic excavator)/manual means over areas including getting out and disposal of excavated earth lead as directed by Engineer-in-charge.	Cubic meter
2/17/2	Soil Nail for Slope Stabilization: Design, providing construction drawings, providing methodology and supply of fully threaded hot rolled (mill threaded), hot-dip galvanized solid geotechnical bars as Soil Nail (galvanization minimum 500 grams per sqm) of required diameter, having yield strength $\geq 670\text{N/mm}^2$ and ultimate tensile strength $\geq 800\text{N/mm}^2$. This rate includes supply of nut, bearing plate, coupler, centralizer, TerraPlug, Horse Shoe, Loop (mechanical connection between soil reinforcement and soil nails), cost of drilling, installation of soil nails and grouting using appropriate machine, manpower, tools, tackles, fuel all complete system assembly as per approved drawing and detailed technical specification.	
2/17/2a	25mm diameter of Soil Nail	Running meter
2/17/2b	28mm diameter of Soil Nail	Running meter
2/17/3	Surface protection works for excavated slope using hot-dip galvanized prefabricated welded steel mesh: Supply and installation of prefabricated flexible galvanized steel mesh of 100mm X 100mm aperture size, made from minimum 6mm dia. bars having minimum galvanization of 500 grams/sqm, welded in such a way that the welding joints of the mesh shall have minimum interpenetration of 8% of the total diameter of the welded bar and having 200mm overlap on vertical joints and horizontal panels jointed using the spiral ring of 4mm dia. including appropriate machine, manpower, tools, tackles, fuel, laying of multilinear geo-composite drainage as sub-surface drainage media, all complete as per the drawing and detailed technical specification.	Square meter

2/17/4	Hybrid/ Composite Reinforced Soil Structure: Design, providing construction drawings, providing methodology of Hybrid/ Composite Reinforced Soil structure including supply and installation of prefabricated flexible galvanized steel mesh (minimum diameter of bar 8mm and galvanization is 500 grams/sqm), maximum 50mm wide geosynthetic strap soil reinforcement made of polyester yarns and encapsulated in LLDPE sheathing with top three layers of soil reinforcement having high coefficient of apparent friction (using trapezoidal grooves on both sides of the geosynthetic strap), active/positive connectors between fascia and soil reinforcement, non-woven geotextile made of polypropylene (minimum mass 160 grams/sqm) including one layer of biodegradable natural geotextile (Erosion control coir blanket) as per detailed technical specification.	Square meter
2/17/5	Supply, laying and compaction of Reinforced Earth fill as per detailed technical specification including, manpower, machinery, tools, tackles, all complete.	Cubic meter
2/17/6	Supply and installation of 100mm dia. (nominal) semi-perforated PVC pipe wrapped with non-woven geotextile to drain out sub-surface water as per approved drawing and detailed technical specification including, manpower, machinery, tools, tackles, all complete.	Running meter
2/17/7	Supply of OPC 52.5 grade cement for the grout mix (50 Kg).	Bags
2/17/8	Supply of non-shrink grout.	Kg
2/17/9	Laying of PCC leveling pad of C15 grade (350mm x 150mm) and PCC required at the toe as per detail drawings including materials, manpower, machinery, tools, tackles, all complete.	Cubic meter
2/17/10	Supply of soil bags behind the steel mesh facing with all consumables as per the detailed technical specification.	No's

2.18 Steel Sheet Piles

2.18.1 Description

This specification outlines the method and resources involved in installation of sheet piles to facilitate works related to shore protection and excavation. Any alternate methods proposed by the contractor shall be at the discretion of Engineer and will have to be prior approved before commencement of work.

2.18.2 Materials

All materials and workmanship shall be in accordance with the appropriate AASHTO, British Standards, Codes of Practice and other specified standards current at the date of tender except where the requirements of these Standards or Codes of Practice are in conflict with this Specification in which case the requirements of this Specification shall take precedence.

2.18.2.a Source of Materials

The approved sources of supply of materials shall not be changed until the Contractor has confirmed that the materials from the new source can meet all the requirements of the Specifications. Materials failing to comply with the Specifications shall be removed promptly from the site.

2.18.2.b Standard Sheet Piles

Unless otherwise specified in the contract, all steel for sheet piles shall conform to ASTM A328/A328M, EN 10248-1, IS 2314:1986, BDS ISO 630, or equivalent standards approved by the Engineer. The steel shall be hot-rolled, with a minimum yield strength of 270 MPa (e.g., S275 or equivalent), and shall include corrosion protection (e.g., epoxy coatings or cathodic protection) suitable for sulfate-rich soils ($\geq 0.2\%$) and riverine conditions. The Contractor shall provide material test certificates verifying tensile strength, elongation, and chemical composition, as per the specified standard.

2.18.2.c Fabricated Sheet Piles and Storage

All fabricated piles, e.g., corners, junctions, box sections, and high modulus sections, shall be fabricated and supplied to the sheet pile manufacturer's recommendations.

2.18.2.d Storage

If sheet piles of different grade steel are stored on site, each pile shall be clearly marked as to its grade and piles of different grades shall be stored separately.

2.18.3 Construction Method

The Contractor shall submit all relevant details of the method of construction of the sheet pile wall and the plant and monitoring equipment he plans to adopt for approval of the Engineer.

2.18.3.a Ground Condition

The Contractor shall report immediately to the Engineer any circumstances which indicate that in the Contractor's opinion, the ground conditions differ from the drawings, or which could have been inferred from the subsurface investigation reports.

2.18.3.b Program of Works for Sheet Piles

The Contractor shall submit to the Engineer each day the intended program of sheet pile wall construction for the following day and shall give 24 hours' notice of his intention to work outside normal hours and at weekends.

The Contractor shall ensure that during the course of the work, displacement or damage does not occur to the completed part of the work or any other elements that has already installed and has been accepted by the Engineer.

2.18.3.c Records

The Contractor shall keep records of sheet pile walls and shall submit two signed copies of these records to the Engineer not later than noon of the next working day after the element was installed.

Any unexpected driving conditions shall be noted in the records.

2.18.3.d Supervision and Control of the Works

The Contractor shall have a competent full-time site supervisor at the site to be in charge for the sheet pile wall construction or installation.

The site supervisor must be experienced in the sheet pile wall construction necessitated by the Contract. The whole time of the site supervisor shall be devoted to the sheet pile wall works. The site supervisor shall not be removed from the Works without the Engineer being notified in advance with at least one week's notice.

The Contractor shall submit to the Engineer his quality plan one week prior to commencement of sheet pile work. Subsequent revisions, amendments or additions shall be submitted to the Engineer for approval prior to their implementation. Quality assurance and quality control documentation shall be made available to the Engineer.

2.18.4 Ordering of Piles

The Contractor shall ensure that the piles are available at the site for driving for incorporation in the Works. All piles and production facilities shall be made available for inspection at all time by the Engineer. Only new piles shall be used for permanent works. Piles shall be carefully examined at the time of delivery. Damaged piles shall be removed from the site. The records of testing of the steel used in the piles shall be submitted to the Engineer for his approval prior to commencing the Works.

2.18.4.a Clutch Sealant

The Contractor shall apply a clutch sealant to the piles prior to pitching in accordance with the manufacturer's recommendations. He shall supply details with his tender of the brand and properties of the clutch sealant he plans to use.

2.18.5 Tolerances on Setting Out

Marker pins for the sheet pile wall positions shall be set out and installed by the Contractor. Prior to installation of the sheet pile wall, the element positions shall be checked by the Contractor and confirmed by the Engineer.

Table 18-1: Dimensional Tolerances for Steel Sheet Pile

S1. No.	Dimension to which Tolerance Applies	Tolerance
1	Width (a) Single piles b) Interlocked piles	$\pm 2\%$ $\pm 3\%$
2	Thickness of section	$\pm 5\%$
3	Weight	$\pm 5\%$
4	Length	± 50 mm
5	Squareness of cut for each section parallel to line of wall perpendicular to line of wall	$\leq 2\%$ ≤ 10 mm
6	Straightness	$\leq 2\%$ of pile length
7	Depth of Section	$\pm 4\%$

2.18.6 Pile Handling and Driving

2.18.6.a Pile Handling

When assembling piles before pitching the Contractor shall ensure that the interlocks are clean and free from distortion. All storage, handling, transporting and pitching of piles shall be carried out in such a way that no significant damage occurs to piles and their coatings.

2.18.6.b Pile Installation

The Contractor shall satisfy himself that the sheet piles can be installed adequately to the correct depths through the reported or anticipated soil conditions. The Engineer shall be notified 24 hours before the commencement of driving.

The piles shall be guided and held in position by temporary gates with each pile properly interlocked with its neighbor. Piles shall not by-pass one another in place of interlocking.

Where sheet piles are driven in panels, the end piles to each panel shall be driven in advance of the general run of piles. After allowing for initial penetration, no pile in the panel shall be driven to an excessive lead in comparison with the toe level of the panel in general and where hard driving is encountered this lead should not exceed 1 m.

At all stages during driving the free length of the sheet pile shall be adequately supported and restrained. The Contractor shall ensure that the sheet panels are driven without significant damage or declutching.

The selection of driving and contracting plant shall be made having due regard to the ground conditions and pile type. The sheet piles shall be driven to the specified level and/or resistance or if hard driving is experienced, to practical refusal (which shall be

defined as when the rate of penetration is below 100 mm per minute when hammering continuously or 12 blows per 25 mm movement when using the appropriate equipment), or when visible damage to the pile occurs. Practical refusal for pile extraction shall be defined generally as when the rate of extraction of a pile is below 100 mm per minute when back-hammering or pulling (with equipment normally capable of withdrawing a pile) continuously (after an initial effort of 10 minutes), or when damage to the pile head occurs. If the piles have not penetrated to the levels specified, or have encountered obstructions, the Contractor shall submit details as to how he will overcome the problem.

Pile driving hammers shall be correctly positioned on the pile so that the hammer will be aligned as near to the axis of the pile as is practically possible. Freely suspended piling hammers shall be equipped with correctly adjusted leg guides and inserts. Where a hammer is mounted in a rigid leader, the leader shall be stable. The anvil block or driving plate shall be of sufficient size to cover as much as possible of the cross-section of pile.

Piles previously driven shall not be used until the Contractor can demonstrate that they can meet all the requirements of the Specification.

The Contractor may provide each pile in more than one length. Spliced joints shall be designed to cater for the combined effects of bearing, shear and bending stresses imposed upon the sheet piles. Splices shall be located to avoid maximum stress positions. If splices are to be welded, then these shall be designed in accordance with the guidelines given in AWS/BS 5135 or equivalent standard and the manufacturer's recommendations. Weld metal shall not encroach within the interlock areas so as not to interfere with the interlocking of the piles.

2.18.6.b Positional and Alignment Tolerance

Unless deflected by obstructions, sheet piles shall be installed within the following tolerances:

- in plan ± 75 mm of the given sheet pile line at commencing surface
- vertical 1 in 75
- level ± 50 mm of required top level.

Pile line dimensions shall be based on the nominal size of piles. Creep or shrinkage of the pile lines shall not exceed the manufacturer's rolling tolerances.

2.18.6.b Welding Standard

For manual metal arc and semi-automatic welding of carbon and carbon manganese steels, welding of piles and steel framework shall be carried out in accordance with AWS / BS 5135 or equivalent. Defective welds shall be cut out and replaced. Where steel piles are to be spliced by butt welding the interlocks shall not be welded unless a sealing weld is required.

2.18.6.b Durability and Protection

All work associated with surface preparation and coating shall be undertaken inside a waterproof structure.

2.19.6.b Piling Records

The following records shall be kept and a copy shall be submitted to the Engineer:

1. Pile reference number or location;
2. Pile type and grade of steel;
3. Pile length;
4. Type of hammer;
5. Date of driving;
6. Commencing surface level;
7. Depth driven;
8. Length of offcuts;
9. Length of pile extensions;
10. The measurement of driving resistance at appropriate depths;
11. All information regarding interruptions, unexpected changes in driving characteristics, obstructions and times taken in overcoming them.

2.18.7 Measurement and Payment

Steel sheet pile shall be measured in unit Metric Tonne. For installed piles directed to be cut off before reaching the penetration depth shown in the Drawing, the portion cut off will not be measured. Depreciation cost shall be considered for usage of same sheet pile multiple times under the same contract.

Payment for Steel Sheet Pile shall cover all costs of furnishing, handling, storing and installing piles including placing, driving, cutting holes and other materials and incidental works as per the Specifications. Pay Item shall be:

Pay Item No.	Description	Unit Measurement
2/18/1	Setting Sheet Piles	Tonne
2/18/2	Setting Sheet Piles (Re-used)	Tonne

Division 3

PAVEMENT WORKS

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3.1 PAVEMENT (MINOR WORKS & PRELIMINARIES)

3.1.1 General

Division 3 of the Specifications covers all requirements for road pavements that will be incorporated in the Works.

3.1.2 Preparation and Stockpiling of Materials

Materials to be used in pavement works shall be processed and stockpiled only in designated areas as approved by the Engineer. The Contractor shall make all arrangements and bear all costs associated with the provision of these storage areas. Preparation and storage of materials along the alignment will not be allowed.

The designated areas shall be cleared of all vegetation and topsoil prior to commencing work and the arrival of any materials. The area will be graded with proper slopes, drained, and well compacted to provide a plane and hard surface for the stockpiling of materials. The area to be used for stockpiling of concrete/bituminous works aggregates shall be a surfaced platform with a well compacted 150 mm thick layer of stone/gravel/brick aggregate or with brick flat soling over a compacted sand bed. The area of surfaced platform will be sufficient enough to allow stockpiling and handling operations of aggregates without intermixing of different types of aggregates or spilling of aggregates outside the surfaced platform at any stage. All necessary measures shall be taken to prevent contamination of aggregates with silt and clay and other deleterious materials during the stockpiling and handling operations. If any aggregate has been stockpiled outside the surfaced platform, the bottom 300 mm of material shall not be used in the concrete/bituminous works; however, it can be used in other un-important works with the permission of the Engineer. Similar kinds of precautions shall be taken during stockpiling and handling of stone boulders to be crushed at the plant site to prevent contamination of their products. In any case, any contaminated aggregate shall not be used in the works.

Bricks of different frog marks, different materials and size fractions shall be kept in separate stockpiles divided as necessary to prevent contamination.

Unless otherwise approved by the Engineer, each stockpile shall be built at least 2 metres high. The Contractor shall supply any planking or other material required in connection with movement of vehicles over and about the stockpiles.

3.1.3 Scarification and Preparation of bed under the existing pavement/or Hard Shoulders

The work shall consist of scarifying the bed under existing pavement/or hard shoulders to a depth up to maximum 200 mm or as ordered by the Engineer and over a width as indicated on the drawings or as instructed by the Engineer upon excavating pit hole before preparing estimate. The excavation of existing pavement/ and hard shoulders shall be done as instructed in the section 2 of these specifications. The material under the existing pavement bed shall be thoroughly mixed by means of a motor grader and homogenised with a pulvimixer or similar approved plant methods. It shall then be

spread and compacted, with the addition of water as may be required, in such manner as to obtain a profile confirming with the lines, grades and cross sections shown on the Drawings, or as directed by the Engineer.

If there is any suitable surplus material this shall be temporarily stockpiled for subsequent reuse in the works, as directed by the Engineer.

Any shortage of materials shall be supplied by the addition of material having engineering characteristics and mix design as specified for the sub-base or base as appropriate and instructed by the Engineer. The additional material shall be thoroughly mixed with the scarified and homogenised material, by means of a motor grader, before compacting.

3.1.4 Repair of Potholes and Damaged Areas of the Existing Bituminous Surfaced Roads

The Engineer may instruct the Contractor to repair potholes or damaged areas on existing bituminous surfaced roads including depressions and broken edges.

The Contractor shall remove the bitumen surface as directed. All damaged and unstable parts of the existing base and sub-base shall be excavated until sound material is reached on all sides and at the base of the excavation. Unsuitable excavated materials shall either be disposed of or stockpiled in locations as directed by the Engineer. The shape of the excavation shall then be made rectangular with vertical sides by cutting the damaged area in proper shapes both in horizontal and vertical direction.

The excavated material, depending on its nature, shall be:

- 1) Stocked adjacent to the Works for reuse, if so directed, or
- 2) Disposed of to spoil, if so instructed in writing by the Engineer.

The bottom of the excavation shall then be shaped, trimmed, watered if necessary, and compacted to the density required for the appropriate pavement layer. The excavation shall then be filled with base material of the type directed by the Engineer in layers after compaction of not thicker than 100 mm. Each layer shall be properly levelled and watered and carefully rammed or compacted with an approved hand vibratory roller, in order to achieve the density required in Section 3.5 for Aggregate Base. A bituminous levelling course or bituminous surfacing will then be placed after applying tack coat to the bottom layer and outer vertical sides, as directed by the Engineer in accordance with the procedure as described in Sections 3.10.3.2, 3.10.3.3 and 3.8.3.4.

3.1.5 Leveling Course

Where shown on the Drawings, or as ordered by the Engineer, a levelling course will be constructed on the existing pavement with the materials required in the Drawings or as otherwise ordered by the Engineer. The execution, measurement and payment of the levelling course works shall be in accordance with the relevant provisions of these Specifications, for the material that will be ordered by the Engineer to be used. If the

thickness of level course is less than 40 mm, it will not consider the part of structural layer asphalt concrete, it will be considered as a part of levelling course when the thickness of levelling is more than 40 mm.

3.1.6 Payment

Preparation and Stockpiling of materials under 3.1.2 will not be paid separately.

The scarification and preparation of Existing Pavement and/or shoulders will be paid for at the Contract unit price for each square metre actually scarified in accordance with the instructions of the Engineer. The price shall be full compensation for all labour, equipment, tools, plant, etc. for scarifying, mixing, homogenising, spreading, watering and compacting, or temporary stockpiling for reuse, and all other incidentals necessary to complete the work specified.

The cost of removing existing layer shall be included in Pay Item No. 3/1/1. The inventory of damaged portion has to be kept in quantity by taking measurement and then approval shall be taken from the Engineer. The damaged portion shall have to be clearly marked. If the damaged portion reaches up to the base or sub-base layers, the portion of base and sub-base layers shall be repaired by appropriate base and sub-base materials respectively and the cost of repair shall be according to pay items of base and sub-base construction.

The repair of Potholes and damaged areas of Existing Bituminous Surfaced roads shall be paid for at the Contract unit rate, on the basis of the volume of excavation filled as ordered by the Engineer. The rate shall include for all excavation, for disposal or stockpiling of resulting material, where ordered, for the compaction of the bottom of the excavation to the specified density, for the supply and placing of sub-base or base material to the specified density along with the supply and placing of the bituminous material, and for all charges related to the proper execution of the work prescribed. The cost of tack coat shall be considered to be included within the rates of this item.

Pay items shall be:

3/1/1	Scarify, Mix and Recomact for repairing Existing Pavement and/or Shoulder	Square Metre
3/1/2	Repair of Potholes on the Existing Pavement	Cubic Metre

3.2 SUB-BASE

3.2.1 Description

This work shall consist of furnishing, placing and compacting sub-base material on a prepared and accepted subgrade or improved subgrade in accordance with these Specifications, and to the lines, levels, grades, dimensions and cross sections shown on the Drawings or as required by the Engineer.

3.2.2 Materials

Material shall be natural or artificial aggregate, free from vegetable matter, soft particles, clay and excess silt. Natural and artificial materials may be mixed together provided they fully conform to all requirements of the Specification and the proportions as approved by the Engineer in writing. If gravel is used as coarse aggregate, it shall contain at least 50% particles (by weight) having broken faces. Natural sand with Fineness Modulus less than 1.0 shall not be allowed to be used in the sub-base material. Sub base materials will be as follows:

- (1) Sub-Base Type I- Stone, mixed with sand.
- (2) Sub-Base Type II: - Brick, construction wastes and dismantling wastes, Recycled Asphalt Pavement (RAP), recovered materials from existing base and sub base wastes produced during the construction of buildings, bridges, roads and similar infrastructures; wastes generated as a result of repair, modification, renewal, demolition or natural disaster of these structures. These wastes include building materials such as concrete, plaster, brick, briquette, asphalt, metal etc.

Sub-base type (Type I or Type II) shall be as mentioned in the Particular Specification.

The material for sub-base shall conform to the requirements given below:

- a) Grading: The grading (washed method) shall conform to grading envelopes A, B or C in Table 3.2-1, as specified in the contract; in case the type of grading is not specified in the contract, it shall be as instructed by the Engineer, whereas grading C may be used in case of minor roads only (less than 3 million ESAL).
- b) Plasticity. The portion of material passing the 0.425 mm sieve shall be of PI not more than 6 when tested in accordance with test procedure STP 3.2.
- c) CBR. The material shall have a 4-day soaked CBR value not less than 40% when compacted to 98% of maximum dry density as determined by STP 4.5 (Vibrating Hammer) or modified hammer as Instructed by the Engineer
- d) Aggregate Impact Value and Los Angeles Abrasion Value: When sampled individually and tested, the test results shall have Los Angeles Abrasion Value, Aggregate Impact Value and water absorption limit as tabulated below.

Test	Sub-base Type I	Sub-base Type II
Los Angeles Abrasion (LAA)	Max 35 %	Max 40 %
Aggregate Impact Value (AIV)	Max 35 %	Max 40 %
Water Absorption	≤ 2%	≤ 15 %

e) If brick is used, Unconfined Compressive Strength (UCS) shall be more than 25 MPa.

Sub-base layer can be divided into two parts, whereas the upper part shall be drainage layer and the lower part shall be filter layer to serve the drainage purpose as proposed in the drawings and approved by the Engineer. In this case each layer should be 150 mm thickness or less but minimum thickness of 100 mm. The filtration compatibility of the sub base layer must be evaluated to separate the sub grade and sub base layer. Geotextiles can be used as the separator in some cases, whereas lower part of sub base layer (dense graded and low permeability) can also be used as the drainage cum filter layer conforming to the grading requirements of the following table containing Grading D envelope.

Table 3.2-1 Grading Requirements for Sub-base Material

Sieve Size (mm)	Percentage by Weight Passing Sieves				
	Grading A	Grading B	Grading C	Grading D (Drainage cum Filter layer)	Tolerance for mix design
53	100	100	--	100	± 1
37.5	85 – 100	80 – 100	--	90 – 100	
19	55 – 95	70 – 90	100	70 – 95	± 6
9.5	35 – 75	55 – 90	70 – 100	55 – 75	± 7
4.75	25 – 60	35 – 65	45 - 85	30 – 55	± 6
2.36	15 – 50	25 – 55	30 – 70	10 – 25	
0.600	7 – 35	20 – 40	15 – 45	2 - 10	± 2
0.300	6 – 27	10 – 15	7 – 30	0 - 6	
0.075	3 – 7	<5	4 - 10	0 - 3	± 1
Minimum CBR Value	40	40	40	40	

3.2.3 Construction Methods

3.2.3.1 Preparation of Subgrade or Improved Subgrade

The subgrade or improved subgrade shall be shaped and compacted in conformity with the provisions of Specifications Sections 2.7 and 2.8 and completed ahead of the placing of the sub-base material. Without any earlier approval, any damage to or deterioration of the subgrade or improved subgrade, including any increase in moisture content above that permitted to achieve the specified compaction, shall be corrected at the Contractors expense before sub-base is laid.

Preparation and surface treatment of the subgrade or improved subgrade shall be carried out only after completion of any specified subgrade drainage and unless otherwise agreed by the Engineer immediately prior to laying the sub-base. The sequence of operations shall be as follows:

- a) The subgrade or improved subgrade shall be regulated and trimmed so that its finished profile shall not vary by more than 20 mm above or below the specified formation level at any point.
- b) The trimmed formation shall be rolled by 1 pass of a smooth wheeled roller having a load per 100 mm width of roll not less than 214 kg or a vibratory roller having a static load per 100 mm width of vibratory roll of not less than 71 kg or a vibratory plate compactor having a static pressure under the base plate of not less than 1,400 kg/m².

3.2.3.2 Provision of Lateral Confinement of Aggregates

While constructing sub-base, arrangement shall be made for the lateral confinement/shoulder of sub-base materials. This shall be done by laying materials in adjoining shoulders along with that of sub-base for which no additional payment will be made.

3.2.3.3 Preparation of Mix

Mix design of the sub-base conforming material and gradation criteria of 3.2.2 shall be approved at least one week before the trial section by the Engineer. Trial mixing proportion of course and fine materials shall be finalized in presence of the Engineer through wash sieve method.

Mixed materials shall be prepared by mechanical means.

While adding water, due allowance should be made for evaporation losses. However, at the time of compaction, water in the mix shall be the optimum value of moisture content. The mixed material should be uniform and no segregation should be permitted.

3.2.3.4 Spreading of Mix

Immediately after mixing, the aggregates shall be spread uniformly and evenly upon the prepared subgrade or improved subgrade in accordance with the layer depth, with

an un-compacted thickness up to 200 mm, subject to the approval of Engineer. In no case shall these be dumped in heaps directly on the area where these are to be laid nor shall their hauling over a partly completed stretch be permitted.

The mix shall be spread by a motor grader. The motor grader shall be capable of spreading the material uniformly all over the surface. Segregation will not be allowed.

The surface of the aggregate shall be carefully checked with templates and all high or low spots remedied by removing or adding aggregate as may be required. The layer may be tested by depth blocks during construction. No segregation of larger and fine particles should be allowed. The aggregates as spread should be of uniform gradation with no pockets of fine materials.

Where the shoulders are of the same as that used for the sub-base course, the material shall be evenly spread in layers, as herein specified, for the full width of the sub-base course and the shoulders simultaneously.

Where the shoulders are not of the same material as that of sub-base course, then the sub base shall be spread to give the required compacted depth and the edge detail shown in the drawings.

When the sub base is spread contiguous to the concrete kerbs or gutters, extreme care shall be exercised not to damage them. Any damage of kerbs or gutters resulting from carelessness or negligent construction methods by the Contractor shall warrant their removal and replacement at the Contractor's sole expense.

3.2.3.5 Sprinkling, Rolling and Compacting

After the mix has been laid to the required thickness, grade and cross fall/camber the same shall be uniformly compacted to the full depth with suitable roller. If the thickness of single compacted layer does not exceed 100 mm, a smooth wheel roller of 80 to 100kN weight may be used. For a compacted single layer upto 150 mm, the compaction shall be done with the help of Vibratory roller of minimum static weight of 80 to 100 kN with an arrangement for adjusting the frequency and amplitude. An appropriate frequency and amplitude may be selected. The speed of the roller shall not exceed 5 km/h.

In portions having unidirectional cross fall/super elevation, rolling shall commence from the lower edge and progress gradually towards the upper edge. Thereafter, roller should progress parallel to the centre line of the road, uniformly over-lapping each preceding track by at least one-third width until the entire surface has been rolled. Alternate trips of the roller shall be terminated in stops at least 1 m away from any preceding stop.

In portions in camber, rolling should begin at the edge with the roller running forward and backward until the edges have been firmly compacted. The roller shall then progress gradually towards the center parallel to the center line of the road uniformly overlapping each of the preceding track by at least one-third width until the entire surface has been rolled.

Any displacement occurring as a result of reversing of the direction of a roller or from any other cause shall be corrected at once as specified and/or removed and made good.

Along forms, kerbs, walls or other places not accessible to the roller, the mixture shall be thoroughly compacted with mechanical tampers or a plate compactor. Skin patching of an area without scarifying the surface to permit proper bonding of the added material shall not be permitted.

If water is required, to bring Sub base material to the correct moisture content, it shall be sprinkled on the surface. The contractor shall supply and sprinkle the necessary water at his own expense. Sub-base material containing excess moisture shall be dried prior to or during compaction. Drying of wet material shall be performed by the methods approved by the Engineer, at the expense of the Contractor.

The Contractor shall carry out a field compaction trial at the start of constructing the sub-base to determine the optimum moisture content and the required number of passes of his particular compaction equipment to comply with the Specification. This trial will also determine the relationship between the loose and compacted thickness in controlling the loose thickness at the time of spreading the mix. The method will require to be approved by the Engineer and shall then be used for all subsequent compaction of sub-base material. Such agreement will not, however, relieve the Contractor of his responsibility and in the event that results later show that the specified compaction is not being achieved, all sub base work shall cease and not be resumed until a fresh trial has been undertaken and a revised compaction method approved by the Engineer.

Rolling should not be done when the sub-grade is soft or yielding or when it causes a wave-like motion in the sub-base. If irregularities develop during rolling which exceed 12 mm when tested with a 3 m straight edge, the surface should be loosened and premixed material added or removed as required before rolling again so as to achieve a uniform surface conforming to the desired grade and cross fall. In no case shall the use of unmixed material be permitted to make up the depressions. The thickness of the finished sub-base shall be on average.

- not less than the required thickness when five thickness measurements are averaged in any 150m length of completed sub-base.
- not thinner than 10mm less than the required thickness at any point.

Sub-base which does not conform to the above requirements shall be corrected by scarifying the full depth of the affected areas, adding or removing materials and re-rolling, watering, if necessary, until the entire surface conforms to the correct levels and cross-falls.

Rolling shall be continued till the density achieved is at least 98 percent of the maximum dry density as determined in accordance with STP 4.5(vibrating hammer) for the material. Light Weight Deflectometer (LWD) test shall be carried out if specified in the Particular Specifications using the following methods:

AASHTO TP 123-01 “Laboratory Determination of Target Modulus Using LWD Drops on Compacted Proctor Mold” and AASHTO TP 456-01 “Compaction Quality Control Using LWD” at frequency of 500 Sqm of sub-base area.

E value obtained from field will be compared with equivalent E value obtained from laboratory CBR with suitable conversion mentioned in AASHTO Design Guide 1993. Field E value shall not be less than laboratory equivalent E value.

After completion, the surface of any finished layer shall be well-closed, free from movement under compaction equipment or any compaction planes, ridges, cracks and loose material. Sub-base which does not conform to the above requirements shall be corrected by scarifying the full depth of the affected areas, adding or removing materials and re-rolling, watering, if necessary, until the entire surface conforms to the correct levels and cross-falls.

The prepared sub-base layer shall be protected against damage until covered by the base course.

3.2.4 Opening to Traffic

No Vehicular traffic shall be allowed on the finished sub base surface. Construction equipment may be allowed with the approval of the Engineer.

3.2.5 Measurement

Sub-base as described in this Section shall be measured by the cubic metres of compacted material in place and accepted. Measurement shall be based on the thickness/cross-section of the sub-base shown on the Drawings and area/length measured on the surface of the road.

3.2.6 Payment

This work measured as provided above shall be paid for at the Contract unit rate per cubic metre for aggregate sub-base, as detailed below. The payment shall be full compensation for furnishing all materials, hauling, placing, compacting, sprinkling, finishing and shaping, and for all labour, equipment, tools and other incidentals necessary to complete the work specified.

Sub-base shall be paid for at the Contract unit rate irrespective of the sources of materials used for constructing the sub base. All costs for excavating existing pavement, or removing existing structures, or savings to the Contractor from re-using materials excavated from existing pavements or structures shall be deemed already covered under pay items 2/2/3, 2/2/4, 2/2/5, 2/9/1 and 2/9/2. If specified, LWD test equipment shall be included in equipment list of Contractor’s Site Laboratory in Sub-Clause 1.3.1, thus no additional payment will be made for this test.

Pay items shall be:

3/2/1(a)	Sub-base (Type-I)	Cubic Metre
3/2/1(b)	Sub-base (Type-II)	Cubic Metre

3.3 AGGREGATE BASE

3.3.1 Description

This work shall consist of a base Type I or Type II, composed of crushed aggregate material placed and compacted on a prepared and accepted sub-base or other base course in accordance with these Specifications and the lines, levels, grades, dimensions and cross sections shown on the Drawings or as required by the Engineer. However, in case of National highways aggregate base type II can be omitted and instead of aggregate base type II, total layer can be constructed as base type I.

3.3.2 Materials

Crushed aggregate shall consist of hard durable particles or fragments of rocks or gravel crushed to the required size, and a filler of coarse sand (F.M. more than 1.5) or other finely divided mineral matter. Use of brick aggregate is not allowed in Base Course.

When the stone is produced from crushed rock, it shall be from a source approved in writing by the Engineer. When produced from gravel, not less than 95% by weight of the coarse aggregate shall be particles having at least one fractured face and not less than 85% by weight of the coarse aggregate shall be particles having at least two fractured faces and, if necessary to meet this requirement or to eliminate an excess of filler, the gravel shall be screened before crushing. Recycled aggregates from base type-I or base type-II may also be used in either course if they satisfy specification requirements and percentage of the recycled to be selected on the result of the performed required tests.

The Contractor shall submit results of material tests on the proposed aggregate base material to the Engineer for his approval at least seven days in advance of its use. Fresh approval shall be required when the material is changed or as per order of the Engineer.

The material for base shall conform to the requirements given below:

- a) Grading: The grading (washed method) shall conform to grading envelope A of Table 3.5-1 for base type-I and either envelope A or B for base type-II.

The material shall be well graded within the envelope with no excess or deficiency of any size; the grading shall not vary from coarser side on one sieve to finer side on another sieve within the grading envelope. The fraction passing the 0.075 sieve shall be not greater than one-third of the fraction passing 0.425 mm sieve.

b) Plasticity: The portion of material passing the 0.425 mm sieve shall be non-plastic, when tested in accordance with test procedure STP 3.2.

c) CBR: When tested in accordance with STP 5.1, the material shall have a minimum soaked CBR value at a compaction of 98% of the maximum dry density as determined by STP 4.5 (Vibrating Hammer) as follows:

Base Type I - 100%

Base Type II - 70%

d) Aggregate Crushing Value/ Los Angeles Abrasion Value (LAA): The coarse part of material sampled and tested in accordance with STP 7.7.1 and AASHTO T96 shall have Aggregate Impact Values (AIV) and Los Angeles Abrasion Value (LAA) as per table 3.3-2.

Table 3.3-1: Grading Requirements for Base Material

Sieve Size (mm)	Percentage by Weight Passing Sieves		Tolerance for mix design
	Grading A	Grading B	
53	100	--	± 1
37.5	90 – 100	--	
19	50 – 85	100	± 6
9.5	30 – 65	80 – 100	± 7
4.75	25 – 50	50 – 80	± 6
2.36	15 – 38	35 – 65	
0.600	8 – 22	15 – 40	± 2
0.300	6 – 16	10 – 30	
0.075	2 – 8	5 – 10	± 1

Table 3.3-2: AIV and LAA Values for Base Materials

Type of Base	AIV (%)	Los Angeles Abrasion Value (%)
Base Type-I	Max 25%	Max 30%
Base Type-II	Max 30%	Max 35%

3.3.3 Construction Methods

3.3.3.1 Preparation of Sub-base

The sub-base or lower base shall be shaped and compacted in conformity with the provisions of Section 3.2, to the correct moisture content and be completed for at least 100 metres ahead of the placing of the base material, unless otherwise approved by the Engineer.

3.3.3.2 Provision of Lateral Confinement of Aggregates

While constructing aggregate base, arrangement shall be made for the lateral Confinement of aggregate base. This can be done by laying materials in adjoining shoulders along with that of aggregate base for which no additional payment will be made.

3.3.3.3 Preparation of Mix

Mix design of the Aggregate Base conforming material and gradation criteria of 3.3.2 shall be approved at least one week before the trial section by the Engineer.

Unless specified different in Particular Specifications, Aggregate Base shall be prepared in an approved mixing plant of suitable capacity having provision for controlled addition of water and forced/positive mixing arrangement like pug-mill or pan type mixer of concrete batching plant. The plant shall have following features.

- i) For feeding aggregates- three/four bin feeders with variable speed motor
- ii) Vibrating screen for removal of oversize aggregates
- iii) Conveyor Belt
- iv) Controlled system for addition of water
- v) Forced/positive mixing arrangement like pug-mill or pan type mixer.
- vi) Centralized control panel for sequential operation of various devices and precise process control.
- vii) Safety devices

Optimum moisture for mixing shall be determined in accordance with STP after replacing the aggregate fraction retained on 22.4 mm sieve with material of 4.75 mm to 22.4 mm size. While adding water, due allowance should be made for evaporation losses. However, at the time of compaction, water in the wet mix should not vary from the optimum value by more than agreed limits. The mixed material should be uniformly wet and no segregation should be permitted. Subject to the approval of the Engineer the Contractor may prepare and spread the Aggregate Base course at site, provided random samples taken at site, tested for gradation and found satisfactory.

3.3.3.4 Spreading of Mix

Immediately after mixing, the aggregates shall be spread uniformly and evenly upon the prepared sub-grade/sub-base/base in required quantities. In no case shall these be dumped in heaps directly on the area where these are to be laid nor shall their hauling over a partly completed stretch be permitted.

Unless specified different in Particular Specifications, the mix shall be spread by a paver finisher for large and important projects. The paver finisher shall be self-propelled of adequate capacity with following features:

- i) Loading hoppers and suitable distribution system, so as to provide a smooth uninterrupted material flow for different layer thicknesses from the tipper to the screed.
- ii) Hydraulically operated telescopic screed for paving width up to 8.5m and

fixed screed beyond this. The screed shall have tamping and vibrating arrangement for initial compaction of the layer.

- iii) Automatic leveling control system with electronic sensing device to maintain mat thickness and cross slope of mat during laying procedure.

However, considering project value and importance, mechanical means like motor grader may be used with the prior approval of the Engineer. The motor grader shall be capable of spreading the material uniformly all over the surface.

The surface of the aggregate shall be carefully checked with templates and all high or low spots remedied by removing or adding aggregate as may be required. The layer may be tested by depth blocks during construction. No segregation of larger and fine particles should be allowed. The aggregates as spread should be of uniform gradation with no pockets of fine materials.

3.3.3.5 Compaction

After the mix has been laid to the required thickness, grade and cross fall/camber the same shall be uniformly compacted to the full depth with suitable roller. If the thickness of single compacted layer does not exceed 100 mm, a smooth wheel roller of 80 to 100kN weight may be used. For a compacted single layer up to 200 mm, the compaction shall be done with the help of Vibratory roller of minimum static weight of 80 to 100 kN with an arrangement for adjusting the frequency and amplitude. An appropriate frequency and amplitude may be selected. The speed of the roller shall not exceed 5 km/h.

In portions having unidirectional cross fall/super elevation, rolling shall commence from the lower edge and progress gradually towards the upper edge. Thereafter, roller should progress parallel to the center line of the road, uniformly over-lapping each preceding track by at least one-third width until the entire surface has been rolled. Alternate trips of the roller shall be terminated in stops at least 1 m away from any preceding stop.

In portions in camber, rolling should begin at the edge with the roller running forward and backward until the edges have been firmly compacted. The roller shall then progress gradually towards the center parallel to the center line of the road uniformly overlapping each of the preceding track by at least one-third width until the entire surface has been rolled.

Any displacement occurring as a result of reversing of the direction of a roller or from any other cause shall be corrected at once as specified and/or removed and made good.

Along forms, kerbs, walls or other places not accessible to the roller, the mixture shall be thoroughly compacted with mechanical tampers or a plate compactor. Skin patching of an area without scarifying the surface to permit proper bonding of the added material shall not be permitted.

Rolling should not be done when the sub-base is soft or yielding or when it causes a

wave- like motion in the aggregate base course. If irregularities develop during rolling which exceed 12 mm when tested with a 3 m straight edge, the surface should be loosened and premixed material added or removed as required before rolling again so as to achieve a uniform surface conforming to the desired grade and cross fall. In no case shall the use of unmixed material be permitted to make up the depressions.

Rolling shall be continued till the density achieved is at least 98 percent of the maximum dry density as determined by STP 4.5(Vibrating Hammer) for the material. Density of the compacted aggregate base course shall be determined in accordance with STP 6.2 (150 mm or 200 mm diameter depending on the layer thickness) with at least three tests being made for each 1,000 square meters.

Besides, if specified in Particular Specification, Light Weight Deflectometer (LWD) test shall be carried out using following methods:

AASHTO TP 123-01 “Laboratory Determination of Target Modulus Using LWD Drops on Compacted Proctor Mold” and AASHTO TP 456-01 “Compaction Quality Control Using LWD” at frequency of 500 Sqm of the Base Course area.

E value obtained from field will be compared with equivalent E value obtained from laboratory CBR with suitable conversion mentioned in AASHTO Design Guide 1993. Field E value will be not less than laboratory equivalent E value.

After completion, the surface of any finished layer shall be well-closed, free from movement under compaction equipment or any compaction planes, ridges, cracks and loose material. All loose, segregated or otherwise defective areas shall be made good to the full thickness of the layer.

3.3.3.6 Setting and Drying

After final compaction of aggregate base course, the road shall be allowed to dry for 24 hours.

3.3.4 Opening to Traffic

No vehicular traffic shall be allowed on the finished surface. Construction equipment may be allowed with the approval of the Engineer.

3.3.5 Surface Tolerance

The finished surface of the aggregate base shall be checked for level and cross fall and at any point shall not vary more than +/-10 mm from the specified level. The surface shall also be checked for irregularities by a 3m long straight edge laid perpendicular and parallel to the road centerline at intervals not exceeding 20 m. The deviation from the straight edge shall not exceed 10 mm. Any areas found to be out of tolerance shall be corrected by loosening, adding or removing material, reshaping and re-compacting.

The thickness of the finished base shall be on average

- Not less than the required thickness when five thickness measurements are averaged

in any 150m length of completed sub-base.

- Not thinner than 10mm less than the required thickness at any point.

The Contractor shall carry out at his own expense, the reconstruction of areas of aggregate base which are too thin or too variable in thickness to meet the requirement.

3.3.6 Rectification of Surface Irregularity

Where the surface Irregularity of the base exceeds the permissible tolerances or where the course is otherwise defective due to sub-base material getting mixed with the aggregates, the full thickness of the layer shall be scarified over the affected area, re-shaped with added premixed material or removed and replaced with fresh premixed material as applicable and recomputed. The area treated in the aforesaid manner shall not be less than 5 m long and 2 m wide. In no case shall depressions be filled up with unmixed and ungraded material or fines.

3.3.7 Measurement

This item shall be measured as the number of cubic metres of material complete in place and accepted. Measurements shall be based on the thickness/cross section of the base shown on the Drawings and the length/area measured on the surface of the road.

3.3.8 Payment

This work measured as provided above shall be paid for at the Contract unit rates per cubic metre for aggregate base irrespective of the sources of material used. Payments shall be full compensation for furnishing all materials, hauling, mixing, placing, compacting, sprinkling, finishing and shaping and for all labour, equipment, tools and other incidentals necessary to complete the work.

All costs of excavating existing pavement, or removing existing structures, or savings to the Contractor from re-using materials excavated from existing pavements, or structures shall be deemed already covered under pay items 2/2/3, 2/2/4, 2/2/5, 2/9/1 and 2/9/2. LWD Test, if specified test equipment shall be included in equipment list of Contractor's Site Laboratory. Thus, no additional payment will be made for this test.

Pay items shall be:

3/3/1	Aggregate Base Type I	Cubic Metre
3/3/2	Aggregate Base Type II	Cubic Metre

3.4 LIME TREATED SOIL FOR IMPROVED SUB-GRADE/SUB-BASE

3.4.1 Description

This work shall consist of laying and compacting an improved sub-grade/lower sub-base of soil treated with lime on prepared sub-grade in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross-sections shown on the drawings or as directed by the Engineer. Lime treatment is generally effective for soils which contain a relatively high percentage of clay and silty clay, whereas the clay percentage is at least 12%.

3.4.2 Materials

Soil:

Except when otherwise specified, the soil used for stabilisation shall be the local clayey soil having a plasticity index greater than 15.

Lime:

Lime for lime-soil stabilization work shall be commercial dry lime slaked at site or pre-slaked lime delivered to the site in suitable packing. Unless otherwise permitted by the Engineer, the lime shall have purity of not less than 70 percent by weight of Quick-lime (CaO). Lime shall be properly stored to avoid prolonged exposure to the atmosphere and consequent carbonation which would reduce its binding properties. Lime content for the stabilization will be within the range 3% to 8% depending upon the soil type.

Quantity of lime in stabilized mix:

Quantity of lime to be added as percentage by weight of the dry soil shall be as required for the CBR/UCS value mentioned in the Particular Specification. The quantity of lime used shall be related to its calcium oxide content which shall be specified. Where the lime of different calcium oxide content is to be used, its quantity shall be suitably adjusted to the approval of the Engineer so that equivalent calcium oxide is incorporated in the work. The mix design shall be done to arrive at the appropriate quantity of lime to be added, having due regard to the purity of lime, the type of soil, the moisture-density relationship, and the design CBR/Unconfined Compressive Strength (UCS) value specified in the Particular Specifications. The laboratory CBR/UCS value shall be at least 1.5 times the minimum field value of CBR/UCS stipulated in the Contract.

Water:

The water to be used for lime stabilization shall be clean and free from injurious substances. Potable water shall be preferred.

3.4.3 Construction Methods

3.4.3.1 Weather limitations:

Lime-soil stabilization shall not be done when the air temperature in the shade is less than 10 °C.

3.4.3.2 Degree of pulverisation:

For lime stabilisation, the soil before addition of stabilizer, shall be pulverized using agricultural implements like disc harrows (only for low volume roads) and rotavators.

3.4.3.3 Soil Pulverisation Requirements for Lime Stabilisation

The soil before addition of stabilizer shall be pulverized using agricultural implements like disc harrows (regional road) and rotavators (National Highways) to the extent that it passes 100 % through 26.6 mm sieve and 80 % passes through 5.6 mm sieve. Type of pulverised equipment shall be as mentioned in the Particular Specification.

3.4.3.4 Equipment for construction:

Stabilised soil sub-bases shall be constructed by mix-in-place method of construction or as otherwise approved by the Engineer. Manual mixing shall be permitted only where the width of laying is not adequate for mechanical operations, as in small-sized jobs.

The equipment used for mix-in-place construction shall be a rotavator or similar/equivalent approved equipment capable of pulverizing and mixing the soil with additive and water to specified degree to the full thickness of the layer being processed, and of achieving the desired degree of mixing and uniformity of the stabilised material. If so desired by the Engineer, trial runs with the equipment shall be carried out to establish its suitability for work.

The thickness of any layer to be stabilised shall be not less than 100 mm when compacted. The maximum thickness can be 200 mm, provided the plant used is accepted by the Engineer.

3.4.3.5 Mix-in-place method of construction:

Before deploying the equipment, the soil after it is made free of undesirable vegetation or other deleterious matter shall be spread uniformly on the prepared subgrade in a quantity sufficient to achieve the desired compacted thickness of the stabilized layer. Where single-pass equipment is to be employed, the soil shall be lightly rolled at the discretion of the Engineer.

The equipment used shall either be of single-pass or multiple pass type. The mixers shall be equipped with an appropriate device for controlling the depth of processing and the mixing blades shall be maintained or reset periodically so that the correct depth of mixing is obtained at all times.

With single-pass equipment the forward speed of the machine shall be so selected in relation to the rotor speed that the required degree of mixing, pulverisation and depth of processing is obtained. In multiple-pass processing, the prepared sub-grade shall be pulverised to the required depth with successive passes of the equipment and the moisture content adjusted to be within prescribed limits mentioned hereinafter. The blending or stabilizing material shall then be spread uniformly and mixing continued with successive passes until the required depth and uniformity of processing have been obtained.

The mixing equipment shall be so set that it cuts slightly into the edge of the adjoining lane processed previously so as to ensure that all the material forming a layer has been properly processed for the full width.

3.4.3.6 Construction with manual means:

Where manual mixing is permitted, the soil from borrow areas shall first be freed of all vegetation and other deleterious mater and placed on the prepared subgrade. The soil shall then be pulverized by means of crow-bars, pick axes or other means approved by the Engineer.

Water in requisite quantities may be sprinkled on the soil for aiding pulverisation. On the pulverized soil, the blending material(s) in requisite quantities shall be spread uniformly and mixed thoroughly by working with spades or other similar implements till the whole mass is uniform. After adjusting the moisture content to be within the limits mentioned later, the mixed material shall be leveled up to the required thickness so that it is ready to be rolled.

3.4.3.7 Addition of lime:

Lime may be mixed with the prepared material either in slurry form or dry state at the option of the Contractor with the approval of the Engineer.

Dry lime shall be prevented from blowing by adding water to the lime or other suitable means selected by the Contractor, with the approval of the Engineer.

The tops of windrowed material may be flattened or slightly trenched to receive the lime. The distance to which lime may be spread upon the prepared material ahead of the mixing operation shall be determined by the Engineer.

No traffic other than the mixing equipment shall be allowed to pass over the spread lime until after completion of mixing. Mixing or remixing operations, regardless of equipment used, shall continue until the material is free of any white streaks or pockets of lime and the mixture is uniform.

Non-uniformity of color reaction, when the treated material is tested with the standard phenolphthalein alcohol indicator, will be considered evidence of inadequate mixing.

3.4.3.8 Moisture content for compaction:

The moisture content at compaction to be determined by trial compaction at site. The moisture content variation determined at compaction shall be ± 2 percent than the optimum moisture content.

3.4.3.9 Rolling:

Immediately after spreading, grading and levelling of the mixed material, compaction shall be carried out with approved equipment preceded by a few passes of lighter rollers if necessary. Rolling shall commence at edges and progress towards the center, except at super elevated portions where it shall commence at the inner edge and progress towards the outer edge. During rolling, the surface shall be frequently checked for grade and crossfall (camber) and any irregularities corrected by loosening the material and removing/adding fresh material. Compaction shall continue until the density achieved is at least 98 percent of the maximum dry density for the material.

Care shall be taken to see that the compaction of lime stabilised material is completed within three hours of its mixing or such shorter period as may be found necessary in dry weather.

During rolling it shall be ensured that roller does not bear directly on hardened or partially hardened treated material previously laid other than what may be necessary for achieving the specified compaction at the joint. The final surface shall be well closed, free from movement under compaction planes, ridges, cracks or loose material. All loose or segregated or otherwise defective areas shall be made good to the full thickness of the layer and recompacted.

3.4.3.10 Curing:

The sub-base course shall be suitably cured for a minimum period of 7 days after which subsequent pavement courses shall be laid to prevent the surface from drying out and becoming friable. No traffic of any kind shall ply over the completed sub-base unless permitted by the Engineer.

3.4.4 Strength

When lime is used for improving the subgrade, the soil-lime mix shall be tested for its CBR value. When lime stabilised soil is used in a sub-base, it shall be tested for unconfined compressive strength (UCS) at 7 days. In case of variation from the design CBR/UCS, in situ value being lower, the pavement design shall be reviewed based on the actual CBR/ UCS values.

3.4.5 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be provided and maintained.

3.4.6 Measurements for Payment

Lime-treated sub-base/1SG shall be measured as finished work in position in cubic metres.

3.4.7 Payment

Lime-treated sub-base/1SG shall be paid for at the contract unit rate irrespective of the sources of materials used for construction.

Pay items shall be:

3/4/1	Lime-treated 1SG	Cubic Metre
3/4/2	Lime-treated sub-base	Cubic Metre

3.5 CEMENT TREATED SUB-BASE/BASE

3.5.1 Description

This work shall consist of laying and compacting a sub-base/base course of sand treated with cement on prepared improved subgrade/sub-base, in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross-sections shown on the drawings or as directed by the Engineer. Mixing and compaction of Cement Treated Sub Base/Base course:

3.5.2 Materials

The material used for cement treatment shall be soil including sand and gravel, laterite, kankar, brick aggregate, crushed rock or slag or any combination of these. It should be free from Clay. It shall have a uniformity coefficient not less than 5, capable of producing a well-closed surface finish. For use in a base course, the material shall be sufficiently well graded to ensure a well-closed surface finish and have a grading within the range given in Table 3.4-1. Plasticity Index value of soil will be less than 5.

Table 3.5-1: Grading Limits of Material for Stabilisation with Cement

Sieve size	Percentage by mass passing
	Sub-Base/Base Within the range
53	100
37.5 mm	95 – 100
19.0 mm	45 – 100
9.5 mm	35 – 100
4.75 mm	25 – 100
600 micron	8 – 65
300 micron	5 – 40
75 micron	0 – 10

Cement:

Cement for stabilization shall either be ordinary portland cement, portland slag cement or Portland-puzzolana cement.

A crack relief layer of dense graded crushed aggregate of 100 mm thickness conforming Table 3.3-1, Grading A shall be provided over Cement treated base to avoid propagation of crack from cement treated base to asphalt layer.

The quantity of cement to be added as percent by weight of the dry mix shall be specified in the mix design and approved by the Engineer. The mix design shall be done on the basis of 7-day unconfined compressive strength (UCS) and/or durability test under 12 cycles of wet-dry conditions. The laboratory strength values shall be at least 1.5 times the minimum field UCS value stipulated in the particular specifications.

Water:

The water to be used for cement stabilisation shall be clean and free from injurious substances. Potable water shall be preferred.

3.5.3 Construction Methods

For pavement design, it's crucial to ensure that the Cement Treated Sub base/Base behaves like a granular material over time, rather than hard concrete, to prevent cracking that could affect the overlying asphalt concrete layers. Here's a structured approach to achieve this:

1. **Combined Gradation:** The combined gradation of aggregates of different sizes in the laboratory shall be determined. Samples shall be taken from various stockpiles or sources of soil/aggregates to ensure uniformity and proper distribution of particle sizes.
2. **Material Preparation:** Air-dry the materials and mix them in a batching plant. This ensures proper blending and consistency of the mixture.
3. **Placement:** Spread the mixed materials evenly on the roadway using a paver. Proper distribution of the material is essential for uniform compaction and performance.
4. **Additives Placement:** Unpack and place packets of cement on top of the placed materials at predetermined intervals. These additives enhance the strength and durability of the treated sub-base course.
5. **Mixing:** Mix all materials thoroughly using a rotavator or similar equipment. This ensures uniform distribution of additives and aggregates throughout the mixture.

6. **Moisture Control:** Sprinkle water onto the bed just enough to facilitate compaction. Proper moisture content is essential for achieving optimal compaction and ensuring the desired properties of the treated base.
7. **Compaction:** Compact the bed using conventional procedures such as rollers or compactors. Adequate compaction is critical to achieving the required density and stability of the treated base course.

3.5.3.1 Weather limitations

Stabilization shall not be done when the air temperature in the shade is less than 10°C.

3.5.3.2 Degree of pulverization:

For stabilization, the soil before addition of stabilizer, shall be pulverized, where Necessary.

3.5.3.3 Moisture content for compaction:

The moisture content at compaction needed to be determined by trial at site.

3.5.3.4 Rolling:

Care shall be taken to see that the compaction of cement stabilized material is completed within initial setting time of cement used or period as instructed by Engineer in dry weather.

3.5.3.5 Curing:

The sub-base/base course shall be suitably cured for 7 days. Subsequent pavement course shall be laid soon after to prevent the surface from drying out and becoming friable. No traffic of any kind shall ply over the completed sub-base unless permitted by the Engineer.

3.5.4 Strength

Cement treated sub-base/base shall be tested for the unconfined compressive strength (UCS) value at 7 days, actually obtained in-situ. In case of variation from the design UCS, in-situ value being on lower side, prior to proceeding with laying of base/surface course on it, the pavement design shall be reviewed for actual UCS value. Laboratory UCS shall be minimum 1.5 times of design UCS as mentioned in Particular Specification. The extra pavement thickness needed on account of lower UCS shall be constructed by the Contractor at his own cost.

3.5.5 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be provided and maintained.

3.5.6 Measurements for Payment

Cement treated sub-base/base shall be measured as finished work in position in cubic metres. Crack Relief Layer if used, shall be measured as finished work in position in cubic metres and will be paid under item 3/3/1.

3.5.7 Payment

Cement treated Sub-base/ Base shall be paid as cubic meters.

Pay items shall be

3/5/1	Cement treated sub-base	Cubic Metre
3/5/2	Cement treated base	Cubic Metre

3.6 GEO-FABRIC REINFORCED SEAL (GRS)

3.6.1 Description

GRS is an effective sprayed sealing technique for treating badly cracked and distressed pavements particularly where the crack movements are slow.

A GRS is produced by:

- Spraying a layer of bitumen (bond/tack coat) on to the existing surface
- Covering the bond coat with an approved fabric and lightly rolling to ensure good adhesion of the fabric
- Application of binder
- Spreading a sealing aggregate
- Rolling to ensure good adhesion of the aggregate to the fabric.

The fabric is incorporated to add strength to the treatment and provide a seal to cope with pavement conditions where conventional binder or polymer binder seals are known to have a reduced life. It can also be used in the bridges in between concrete surface and asphalt treatment. To minimize the risk of de-bonding of asphalt placed on a GRS, GRS should be trafficked until it is firmly bonded to the base structure prior to placement of the asphalt. The length of time that a GRS can be trafficked may be restricted by the location and service conditions.

3.6.2 Materials

Geotextile Fabric Materials

Geotextiles used for sprayed sealing are conventionally manufactured from polymers, the most frequently used being polyester and polypropylene. The fabric should be non-woven, needle-punched and formed from mechanically entangled filaments. Geotextiles made from continuous filaments are preferred.

Geotextile fabric shall have the properties shown in Table 3.6-1 below.

Table 3.6-1: Geotextile fabric properties

Property	Recommended Minimum	
	Light Fabric Grade	Heavy Fabric Grade
Mass (g/m ²)	130	175
Thickness (mm)	1.5	1.8
Elongation at ultimate strength (%)	50	50
G Value (Robustness)	950	950
Bitumen saturation (L/m ²)	0.9	1.1
Melting Point (°C)	165	165

A minimum fabric mass of 130 g/m² is recommended for sealing applications. However, when a GRS is used on expansive clays or untreated soft pavements, and larger sized sealing aggregates (e.g. > 10 mm) are proposed, a heavier grade of fabric with a fabric mass of ≥ 175 g/m², should be used to reduce the risk of puncturing of the fabric.

Storage and Handling of Geotextile Fabric

Geotextile fabrics should be stored in dry areas, in their shipping bags, and away from direct sunlight for protection from moisture infiltration and UV degradation. The core of the fabric roll should be a smooth bored PVC pipe and not cardboard. Cardboard cores are more likely to crush during handling, particularly if affected by moisture. A wet geotextile fabric should not be used as the potential for aggregate stripping is increased.

Fabric Selection

A minimum fabric mass of 130 g/m² is used for general sealing applications with 10 mm aggregate. Where larger sealing aggregates are proposed, heavier grades of fabric (175 to 200 g/m²) should be used. Geotextiles made from polyester are preferred when using hot bitumen as they have a higher melting point. Where polypropylene fabric is used the binder temperature should not exceed 170°C.

Other Materials

All other materials are to be as per Section 3.12 Bitumen Surface Treatment.

Pre-sealing Considerations

Pre-sealing requirements for GRS are the same as for conventional seals. The usual rules for good surface preparation and sealing practices apply. This will ensure the maximum effective life for the treatment.

Stabilized Heavy-Duty Pavements

For stabilized pavements in heavy duty conditions (e.g. > 1x10⁷ ESAs or exceeding 500 vehicles/lane/day), the surfacing must be prime sealed, primed and sealed or sealed prior to the application of the GRS. This will be more effectively anchor the GRS to the base. This also ensures that a rough interface is achieved for both retention of the seal under traffic and to avoid a slip layer under future asphalt overlays.

Texture Correction

Where the existing surface texture is too coarse for the proposed GRS aggregate or irregular, then a correction course comprising a small sized aggregate seal or reseal, should be applied well in advance of a GRS.

When the existing surface is smooth, with little or no texture, or is recently applied asphalt or slurry surfacing, then a small sized aggregate seal should be applied at least six weeks in advance to provide a friction key for the GRS.

Pre-spraying of Un-trafficked Areas

Un-trafficked areas, (along the centerline, outer edges and between wheel tracks), may be pre-sprayed with 0.2 to 0.3 L/m² bitumen (usually 80/100) in advance of the bond coat or after the application of the geotextile, particularly if the texture is hungrier in those areas.

3.6.3 Construction Method

3.6.3.1 General

Generally, construction method shall be as per Section 3.12.3 except where noted differently below.

3.6.3.2 Sequence of Operations

A typical order of operations is shown in Table 3.6-2. There may be slight variations to this order for particular circumstances, e.g. if the bond coat bleeds through the geotextile, a seven mm aggregate may need to be spread prior to or during rolling of the geotextile.

Table 3.6-2: Typical Sequence of Operation for Geotextile Reinforced Seals

Order of Operations	Operation
1	Surface preparation
2	Bond (tack) coat
3	Apply geotextile
4	Roll geotextile
5	Spray binder
6	Apply aggregate
7	Roll aggregate
8	For a double/double seal the second application would be applied in the normal manner

3.6.3.3 Surface Preparation

For natural surface or clay formations, the relative compaction of the pavement should comply with the appropriate specifications.

Preferred practice for unsealed bases is to first apply a prime or primer seal. Priming is recommended where a GRS is to be applied to a granular or modified pavement (particularly stabilized), timber or concrete surfaces.

Before spraying, the surface should be cleaned, swept and given a light spray with water (if not primed or primer sealed) to promote penetration.

GRSs are used to treat pavements that have the potential to, or are already, extensively cracked without any pre-treatment, provided the cracks are less than 3 mm in width. Larger cracks should be pre-treated with one or a combination of the following:

- Fill with emulsion and grit
- Hot or cold modified bitumen crack sealants. (When using this method cracks should be filled but not over banded)
- Fine asphalt or slurry mixes.

Other defects, e.g. ruts, potholes, shoving, edge defects, etc., should be repaired before resealing.

As a general rule, any correction seal, crack filling and pavement repairs should be completed at least six weeks in advance of the application of the GRS to reduce the risk of bleeding or flushing.

3.6.3.4 Weather Conditions

GRS are specialized treatments and should only be placed in dry warm conditions. Preferred conditions are:

- Predicted fine weather for next few days

- Little or no wind (to reduce billowing of fabric)
- Dry Pavement
- Dry surface to avoid trapping moisture under the GRS.

3.6.3.5 Equipment

The plant used for conventional sprayed sealing operations can be used for geotextile reinforced sealing. The use of pneumatic-type multi-wheel rollers of less than 15 t mass is preferred to lessen the risk of embedment of aggregate and/or crushing the aggregate.

In addition, a fabric applicator such as the one shown in Figure 3.6-1 is required. This is usually a lightweight frame attached to a loader (smaller, non-articulated loaders are preferred), or other similar plant item, with a spindle to hold the roll of geotextile. A spring-loaded broom arrangement and/or tensioning bar is attached at the base of the frame to press the fabric firmly onto the pavement surface to prevent wrinkling. There should be a special tension control mechanism to ensure a uniform fabric tension during application. Frames can be manufactured locally or can usually be hired or purchased from geotextile suppliers.

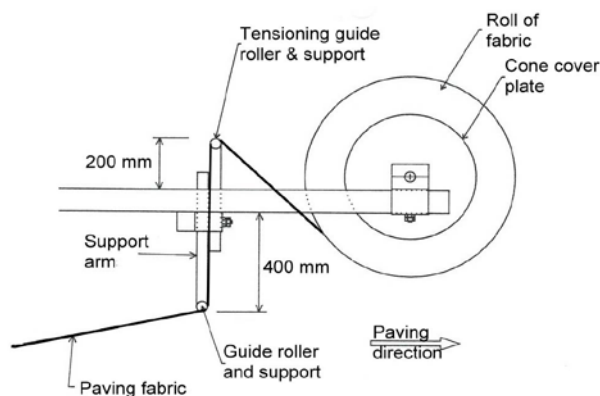


Figure 3.6-1: Schematic of a Fabric Spreader

3.6.3.6 Spraying

It is accepted practice that the edges of the geotextile are covered by the seal.

3.6.3.7 Bond (tack) coat

The binder used for a bond coat is usually a 80/100 bitumen, ideally without cutter oil. Where the pavement material is relatively permeable, and where priming or primer sealing has not been carried out in advance, a small amount of cutter oil (up to 3%) may be used in the bond coat to promote penetration. If too much cutter oil is used in the bond coat (e.g. >3%) the evaporation of volatiles will be slow, and in hot weather this can cause bubbling in the sealed surface.

The bond coat binds the fabric onto the road surface during sealing and the application rate used ranges between 0.4 and 1.0 L/m² (cold).

The amount of bond coat applied is part of the total design binder application rate.

The bond coat should be sufficient to secure the fabric during application and sealing operations, without causing the binder to bleed through the fabric during placement or subsequent rolling.

Ideally, cutter oil should not be used in bond coats over impermeable pavements such as clay pavements or heavily bound base materials, as the cutter oil will be trapped in the geotextile, leading to softening of the seal and possible aggregate stripping. The bond coat should be sprayed wider than the width of the geotextile to be laid, to allow the final seal to protect the edges of the geotextile.

If the geotextile is to be placed in two or more adjacent runs, the bond coat should be sprayed one run at a time, prior to placing each run of geotextile. The overlap width for the geotextile should be about 100 to 200 mm and must be fully saturated with bitumen to minimize the potential for aggregate stripping along the join. To achieve this, the overlap area is sprayed twice – the second spray run overlapping the first run of geotextile.

3.6.3.8 Placement of Geotextile Fabric

The geotextile should be rolled out slowly (using a fabric applicator) immediately after spraying the bond coat, and as close behind the sprayer as practicable.

The unfurling fabric should be kept as low as possible to the ground to prevent billowing and should be kept taut to minimize wrinkling. Wrinkles should be broomed out, or cut and butted where necessary.

Adjoining or adjacent rolls should be overlapped by 100 to 200 mm, with the overlapped join receiving additional binder as described above. Placing of fabrics along straight alignments is generally problem free.

Where the geotextile is to be placed around a significant curve, it should be ‘cut and butted’ at regular intervals along the inner side of the curve. Any overlaps should be hand sprayed with additional bitumen so that the geotextile is fully saturated. Wrinkles larger than 25 mm should be treated as overlaps.

Care must be taken to ensure overlaps do not occur in the wheel path areas.

On clay formations, the fabric should be laid as wide as possible over the shoulder area of the pavement, to prevent shoulder erosion and ingress of moisture. For other applications, the fabric should be applied over the full width of the pavement or trafficked lane width, as appropriate.

The fabric should be lightly rolled prior to the application of binder.

If rolling and/or construction traffic causes the bond coat to bleed up through the fabric, a binding coat of 7 mm aggregate may be applied in advance of sealing to prevent pick-up.

Rollers or vehicles should not stand on the laid fabric as this may lead to a build-up of binder on the surface of the fabric.

3.6.3.9 Binder Seal

The binder is usually Class 85/100 bitumen and may be cutback as per normal sealing practice. It should be sprayed onto the geotextile at GRS design rate following placement of the geotextile.

Bitumen should not be sprayed onto the geotextile if the geotextile has become wet, as the presence of moisture will lead to subsequent seal loss. For this reason, sealing should not commence unless the seal over the geotextile can be applied well before any rain or inclement weather occurs.

3.6.3.10 Aggregate Spreading and Rolling

Aggregate should be spread onto the binder as soon as possible after spraying. Rolling should be carried out with a rubber tyred roller with the rolling sequence being from the middle outwards to the edges.

3.6.3.11 Trafficking

Traffic can be used to assist with compaction of the GRS as in conventional sealing practices. For double/double treatments, slow moving traffic should be allowed onto the GRS after the first layer of aggregate has been placed. Speed restrictions may be required until the aggregate and binder are firmly adhered to the geotextile.

For treated pavements, trafficking of the fabric (i.e., no aggregate cover) may be permitted in extreme circumstances such as plant breakdowns and emergencies, provided traffic speeds are kept low and the time of trafficking is minimized.

3.6.3.12 Caution

If the exposed fabric becomes wet (unexpected storm or accident) the surface becomes very slippery and trafficking should be halted immediately and not recommended until the surface is completely dry. Where practical, a physical barrier should be erected to prevent trafficking of the wet, exposed fabric.

3.6.3.13 Reduced Daily Production

When programming GRS operations, allowance may be made for reduced area compared to normal sealing works. This is due to the additional requirements for the application of the bond coat and geotextile and the additional rolling requirements.

3.6.4 Maintenance

Where a clay pavement surfaced with a GRS has been subjected to flooding, it should be allowed to dry back prior to reopening to traffic. It should then be rolled with a pneumatic tyred multi tyred roller from the inside (Centre of pavement) to the outside before being opened to traffic. Premature opening, particularly to heavy vehicles and four-wheel drives, is likely to cause debonding of the GRS from pavement and pavement deformation.

3.6.5 Measurement

The GRS works of the type stated in the Bill of Quantities shall be measured in square meter of the completed and accepted works as detailed on the Drawings or as directed by the Engineer.

3.6.6 Payment

Payment shall be full compensation for trial mixes, furnishing, and placing all materials, including all labour, equipment, tools and incidentals necessary to complete the Works.

Where defective work is corrected, or additives used which have not been specified or ordered by the Engineer, no payments will be made in respect of extra work or materials used in excess of the quantities specified or ordered. The use of adhesive, anti-stripping agent bitumen additive etc will not be paid for separately, and any costs involved should be included within pay item 3/6/1. Pre-coating of chippings shall be carried out without any additional payment.

Pay items shall be:

Pay Item No.	Description	Unit Measurement
3/6/1	Single GRS Surface Treatment	Square Meter
3/6/2	Bituminous Tack Coat (plant work)	Square Meter
3/6/3	Bituminous Tack Coat (labour intensive work)	Square Meter

3.7 BITUMINOUS MATERIALS

3.7.1 Description

This Section specifies the bituminous materials to be used in the work.

3.7.2 Material

The materials shall be as indicated in the Contract Documents. If materials are not completely described, materials suitable for the purpose and in accordance with generally recognised good practice should be used. Material shall meet the requirements for one of the following types.

3.7.2.1 Bitumen

3.7.2.1.1 Penetration Grade Bitumen

Bitumen shall generally conform to the requirements as ASTM D946-20 (Standard Specification for Penetration-Graded Asphalt Binder for Use in Pavement Construction). In all direct pavement construction works and major maintenance, only bitumen of Penetration Grade 40-50 or 60-70 will be used as specified below. Penetration Grade 85-100, 120-150 and 200-300 can be used for preparation of Modified bitumen, sealant and fillers. The samples should be free of water which can be found through ASTM D95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation.

An adjustment to ASTM D946 with two additional parameters shall be included for RHD approved bitumen, which are:

1. Softening Point (°C) for Pen Grade 40-50 should be 52 to 60 (min to max) and for Pen Grade 60-70 shall be 50-56 (min to max) (in place of ASTM D946 specified value of 49 and 46 (min value), respectively.)
2. Specific Gravity for Pen 40-50 and 60-70 bitumen shall be 1.01-1.05, whereas for 85-100, it will be 0.99-1.04.

Table 3.7-1: ASTM D946 Specification for Penetration Grade Bitumen with adjustments

Requirements for Penetration-Graded Asphalt Binder for Use in Pavement Construction.										
	Penetration Grade									
	40-50		60-70		85-100		120-150		200-300	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Penetration at 25 °C, 100 g, 5 s	40	50	60*	70	85	100	120	150	200	300
Softening Point, °C	52	60	50	56	42		38		32	
Flash point, °C. (Cleveland open cup)	230	...	230	...	230	...	220	...	175	...
Ductility at 25 °C, 5 cm/min, cm	100	...	100	...	100	...	100	...	100 ⁴	...
Solubility, %wt	99.0	...	99.0	...	99.0	...	99.0	...	99.0	...
Specific Gravity	1.01	1.05	1.01	1.05	0.99	1.04				
Retained penetration after thin-film oven test,	55+	...	52+	...	47+	...	42+	...	37+	...
%Ductility at 25 °C, 5 cm/min, cm after thin-film oven test	...	...	50	...	75	...	100	...	100 ⁴	...
^A If ductility at 25 °C is less than 100 cm, material will be accepted if ductility at 15 °C is 100 cm minimum at the pull rate of 5 cm/min. ^B The reference test method is D1754/D1754M. Optionally, Test Method D2872 may be used as agreed between the purchaser and the seller. The two test methods give different degrees of heat conditioning (D2872 is more severe), so the two methods may give different results for retained penetration and ductility. *Lower than 60 may be acceptable.										

Following ASTM test procedures should be maintained for measurement of above-mentioned values.

1. Sampling—STP 2.7/ ASTM D140/D140M.
2. Penetration—STP 10.1/ ASTM D5/D5M (same as AASHTO T49)
3. Softening Point— STP 10.2/ ASTM D36/D36M.
4. Flash Point— STP 10.5/ ASTM D92.
5. Ductility—ASTM D113.
6. Thin Film Oven Test—ASTM D1754/D1754M or Rolling Thin Film Oven Test—ASTM D2872
7. Solubility in Trichloroethylene—ASTM D2042 or Solubility in N-Propyl Bromide—ASTM D7553

3.7.2.1.2 Performance Grade Bitumen

The performance grade bitumen is used for the acceptance purposes that must be met under certain climatic and aging conditions. This standard system is part of the Superpave system. For specific projects with access to advanced Superpave Performance Grading (PG) equipment, ASTM D8239-21 (Standard Specification for Performance-Graded Asphalt Binder Using the Multiple Stress Creep and Recovery (MSCR) Test). In all direct pavement construction works and major maintenance, only bitumen of PG High Temperature Grade 58-XX or above will be used as specified below (exact grade should be selected based on geological location and climatic condition). For low temperature grade, PG XX-10 should be selected. MSCR grade requirement should be adjusted based on traffic level and should be 'S' grade for routine works with unmodified bitumen.

Table 3.7-2: ASTM D8239 Specification (adjusted for approved grades) for PG Bitumen

Grade range (High temp)	PG 58	PG 64	PG 70	PG 76	PG 82
Grade range (Low Temp)	-16	-10	-10	-10	-10
Average 7-day maximum pavement design temperature (°C)	< 58	< 64	< 70	< 76	< 82
Minimum pavement design temperature (°C)	> -16	> -10	> -10	> -10	> -10
Original binder					
Flash-point temperature, D92; min. (°C)	230	230	230	230	230
Viscosity, D 4402: max. 3 Pa × s, test temperature (°C)	135	135	135	135	135
Dynamic shear, D7175: $G^*/\sin\delta$, min. 1.00 kPa; 25 mm plate, 1 mm gap; test temperature at 10 rad/s (°C)	58	64	70	76	82
Rolling thin film oven residue (ASTM D2872)					
Mass loss, max. %	1.0	1.0	1.0	1.0	1.0
Dynamic shear, D7175: $G^*/\sin\delta$, min. 2.20 kPa; 25 mm plate, 1 mm gap; test temperature at 10 rad/s (°C)	58	64	70	76	82
MSCR, D7405, Standard Traffic, 'S', Jnr3.2, max 4.5 kPa-1 Jnr diff, max 75%, Test temp, °C	58	64	70	76	82
MSCR, D7405, Standard Traffic, 'H', Jnr3.2, max 2 kPa-1 Jnr diff, max 75%, Test temp, °C	58	64	70	76	82
MSCR, D7405, Standard Traffic, 'V', Jnr3.2, max 1 kPa-1 Jnr diff, max 75%, Test temp, °C	58	64	70	76	82
MSCR, D7405, Standard Traffic, 'E', Jnr3.2, max 0.5 kPa-1 Test temp, °C	58	64	70	76	82
Pressure ageing vessel residue (ASTM D6521)					
PAV ageing temperature (°C)	100	100	100 (110)	100 (110)	100 (110)
Dynamic shear, D7175: $G^* \times \sin\delta$, max. 6000 kPa; 8mm plate, 2 mm gap; test temperature at 10 rad/s (°C)	25	31	34	37	40
Creep stiffness, D 6648: S, max 300 MPa; m-value, min. 0.300; test temperature at 60 s (°C)	-6	0	0	0	0
Direct tension, D6723: failure strain, min. 1.0%; test temperature at 1.0 mm/min. (°C)	-6	0	0	0	0

*** In MSCR test, the Standard S grade, traffic < 3 million ESAL; Heavy H Grade traffic > 3 million ESAL; for Very Heavy V Grade, traffic > 10 million ESAL and Extreme E grade traffic > 30 million ESAL.*

Following test procedures should be followed for measurement of above-mentioned values:

1. STP 10.5/ ASTM D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
2. STP 2.7/ ASTM D140/D140M Practice for Sampling Asphalt Materials
3. ASTM D2042 Test Method for Solubility of Asphalt Materials in Trichloroethylene
4. ASTM D2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
5. ASTM D4402/D4402M Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer
6. ASTM D6373 Specification for Performance-Graded Asphalt Binder
7. ASTM D6521 Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
8. ASTM D6648 Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
9. ASTM D7175 Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer
10. ASTM D7405 Test Method for Multiple Stress Creep and Recovery (MSCR) of Asphalt Binder Using a Dynamic Shear Rheometer

3.7.2.1.3 Polymer Modified Bitumen

For high-degree of heat and rut resistance, Polymer modified bitumen (PMB) may be selected. Using advanced Superpave PG Grading equipment, PMB should be compliant to ASTM D8239-21 (Standard Specification for Performance-Graded Asphalt Binder Using the Multiple Stress Creep and Recovery (MSCR) Test). This code is a direct equivalent to AASHTO M332 specification.

For all direct pavement construction works and major maintenance, only bitumen of PG High Temperature Grade 64-XX or above will be used as specified below (exact grade should be selected based on geological location and climatic condition). For low temperature grade, PG XX-10 should be selected. Only Elastomeric Polymers, such as SBS, are currently accepted for use in PMB.

MSCR grade requirement should be adjusted based on traffic level and should be at least 'H' grade, when tested at the required High Temperature Grade, found from 7-day maximum pavement temperature measured over 98% reliability level. 'V' or 'E' grade should be selected for high level of traffic, such as 10-30 MESA or 30+ MESA traffic, respectively. More stringent Jnr value ($<0.2 \text{ kPa}^{-1}$) can be selected for extremely high degree of traffic.

Adjustments to ASTM D8239: In addition to the table provided below, PMB should have the following properties, such as

1. Separation/storage stability, difference in softening point, °C= max 2.2. (ASTM D7173)

Table 3.7-3: ASTM D8239 Specification (adjusted for approved grades) for Polymer Modified Bitumen

Grade range (High temp)	PG 58	PG 64	PG 70	PG 76	PG 82
Grade range (Low Temp)	-16	-10	-10	-10	-10
Average 7-day maximum pavement design temperature (°C)	< 58	< 64	< 70	< 76	< 82
Minimum pavement design temperature (°C)	>-16	>-10	>-10	>-10	>-10
Original binder					
Flash-point temperature, D92; min. (°C)	230	230	230	230	230
Viscosity, D 4402: max. 3 Pa × s, test temperature (°C)	135	135	135	135	135
Dynamic shear, D7175: $G^*/\sin\delta$, min. 1.00 kPa; 25 mm plate, 1 mm gap; test temperature at 10 rad/s (°C)	58	64	70	76	82
Rolling thin film oven residue (ASTM D2872)					
Mass loss, max. %	1.0	1.0	1.0	1.0	1.0
Dynamic shear, D7175: $G^*/\sin\delta$, min. 2.20 kPa; 25 mm plate, 1 mm gap; test temperature at 10 rad/s (°C)	58	64	70	76	82
MSCR, D7405, Standard Traffic, 'S', Jnr3.2, max 4.5 kPa-1 Jnrdiff, max 75%, Test temp, °C	58	64	70	76	82
MSCR, D7405, Standard Traffic, 'H', Jnr3.2, max 2 kPa-1 Jnrdiff, max 75%, Test temp, °C	58	64	70	76	82
MSCR, D7405, Standard Traffic, 'V', Jnr3.2, max 1 kPa-1 Jnrdiff, max 75%, Test temp, °C	58	64	70	76	82
MSCR, D7405, Standard Traffic, 'E', Jnr3.2, max 0.5 kPa-1 Test temp, °C	58	64	70	76	82
Pressure ageing vessel residue (ASTM D6521)					
PAV ageing temperature (°C)	100	100	100 (110)	100 (110)	100 (110)
Dynamic shear, D7175: $G^* \times \sin\delta$, max. 6000 kPa; 8mm plate, 2 mm gap; test temperature at 10 rad/s (°C)	25	31	34	37	40
Creep stiffness, D 6648: S, max 300 MPa; m-value, min. 0.300; test temperature at 60 s (°C)	-6	0	0	0	0
Direct tension, D6723: failure strain, min. 1.0%; test temperature at 1.0 mm/min. (°C)	-6	0	0	0	0

Following ASTM test procedures should be followed for measurement of above-mentioned values:

1. STP 10.5/ ASTM D92 D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
2. ASTM D140/D140M Practice for Sampling Asphalt Materials
3. ASTM D2042 Test Method for Solubility of Asphalt Materials in Trichloroethylene
4. ASTM D2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
5. ASTM D4402/D4402M Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer
6. ASTM D6373 Specification for Performance-Graded Asphalt Binder
7. ASTM D6521 Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
8. ASTM D6648 Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
9. ASTM D7175 Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer
10. ASTM D7405 Test Method for Multiple Stress Creep and Recovery (MSCR) of Asphalt Binder Using a Dynamic Shear Rheometer

In absence of availability of Dynamic Shear Rheometer, ASTM D5976-00 standard may be utilized for PMB specification. It should be emphasized that all viable means of getting DSR access (essential for ASTM D8239) should be exhausted before allowing ASTM D5976-00. Type I PMB of I-C and I-D is allowed for application in road construction.

Table 3.7-4: ASTM D 5976 Specification for Polymer Modified Bitumen (In absence of DSR)

Physical Property Requirements for Type I Polymer-Modified Asphalts								
Designation	I-A		I-B		I-C		I-D	
	Min	Max	Min	Max	Min	Max	Min	Max
Penetration at 25 °C [77 °F]. 100 g, 5 s, dmm	100	150	75	100	50	75	40	75
Viscosity, 60°C (140°F). 1 s ⁻¹ . poise ^A	1250		2500		5000		50000	
Viscosity, 135°C (275°F), cSt		2000		2000		2000		5000
Flash Point, COC, °C (°F)	232 (450)		232 (450)		232 (450)		232 (450)	
Solubility in trichloroethylene, %	99		99		99		99	
Separation, difference, °C (°F)		2.2 (4)		2.2 (4)		2.2 (4)		2.2 (4)
Test on RTFOT Residue ^B								
Elastic recovery, 25°C (77°F). 10 cm elongation, %	70		70		70		70	
Penetration, 4°C (39.2°F), 200 g, 60 s, dmm	20		15		13		10	
Softening point°C	70		70		70		70	
^A The absolute viscosity should be run in a modified Koppers or Asphalt Institute vacuum capillary viscometer. Report the viscosity at a shear rate of 1 reciprocal second.								
^B The thin film oven test may be used, but the rolling thin film test shall be the referee method.								

Following test procedures should be followed for measurement of above-mentioned values:

1. STP 10.1/ ASTM D5 Test Method for Penetration of Bituminous Materials
2. STP 10.2/ ASTM D 36 Test Method for Softening Point of Bitumen (Ring and-Ball Apparatus)
3. STP 10.5/ ASTM D 92 Test Method for Flash and Fire Points by Cleveland Open Cup
4. ASTM D 113 Test Method for Ductility of Bituminous Materials
5. STP 2.7 ASTM D 140 Practice for Sampling Bituminous Materials
6. ASTM D 1754 Test Method for Effect of Heat and Air on Asphaltic Materials (Thin-Film Oven Test)
7. ASTM D 2042 Test Method for Solubility of Asphalt Materials in Trichloroethylene
8. STP 10.6/ ASTM D 2170 Test Method for Kinematic Viscosity of Asphalts (Bitumen)
9. ASTM D 2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
10. ASTM D 4957 Test Method for Apparent Viscosity of Asphalt Emulsion Residues and Non-Newtonian Bitumen by Vacuum Capillary Viscometer
11. ASTM D 6084 Test Method for Elastic Recovery of Bituminous Materials by Ductilo meter

3.7.2.1.4 Crumb Rubber Modified Bitumen

Due to lack of previous application in the context on Bangladesh, use of Crumb Rubber shall not be allowed in present condition.

3.7.2.1.5 Cut-Back Bitumen

Three types of cutback bitumen will be used. They are: Rapid Curing (RC), Medium Curing (MC) and Slow Curing (SC) Cutback bitumen. Tests performed to exhibit adherence to specification is valid for 14 days. Specification outlining properties of each type is given below:

Rapid Curing (RC) Cut-Back Bitumen:

ASTM D2028 shall be adopted as the standard specification for rapid curing cutback bitumen. Following Table shall be utilized to identify different grades of Rapid Curing Cutback Bitumen.

Table 3.7-5: ASTM D2028 Specification for Rapid Curing Cutback Bitumen

Requirements for Cutback Asphalt (Rapid-Curing Type)								
NOTE 1-If the ductility at 25°C [77°F] is less than 100, the material will be acceptable if its ductility at 15°C [59°F] is more than 100.								
Designation	RC-70		RC-250		RC-800		RC-3000	
	Min	Max	Min	Max	Min	Max	Min	Max
Kinematic viscosity at 60°C [140°F], mm ² s	70	140	250	500	800	1600	3000	6000
Flash point (Tag open-cup), °C [°F]	...	...	27 [80]	...	27 [80]	...	27 [80]	...
Distillation test: Distillate, volume percent of total distillate to 360°C (680°F):								
to 190°C	10	...	...	...	...	...	...	...
to 225°C	50	...	35	...	15	...	...	...
to 260°C	70	...	60	...	45	...	25	...
to 316°C	85	...	80	...	75	...	70	...
Residue from distillation to 360°C	55	...	65	...	75	...	80	...
percent volume by difference								
Tests on residue from distillation:								
Viscosity at 60°C], Pa-s ^A	60	240	60	240	60	240	60	240
Ductility at 25°C cm	100	...	100	...	100	...	100	...
Solubility, %	99.0	...	99.0	...	99.0	...	99.0	...
Water, %	...	0.2	...	0.2	...	0.2	...	0.2
^A Instead of viscosity of the residue, the specifying agency, at its option, can specify penetration at 100 g: 5 s at 25°C (77°F) of 80 to 120 for Grades RC-70, RC-250, RC-800, and RC-3000. However, in no case will both be required.								

Medium Curing (MC) Cut-Back Bitumen

ASTM D2027 will be adopted as the standard specification for medium curing cutback bitumen. Following Table will be utilized to identify different grades of Medium Curing Cutback Bitumen.

Table 3.7-6: ASTM D2027 Specification for Medium Curing Cutback Bitumen.

Requirements for Cutback Asphalt (Medium-Curing Type)										
NOTE 1-If the ductility at 25 °C [77 °F] is less than 100, the material will be acceptable if its ductility at 15 °C [59 °F] is more than 100.										
Designation	MC-30		MC-70		MC-250		MC-800		MC-3000	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Kinematic viscosity at 60°C [140°F], mm ² /s	30	60	70	140	250	500	800	1600	3000	6000
Flash point (Tag open-cup), °C [°F]	38 [100]	...	38 [100]	...	66 [150]	...	66 [150]	...	66 [150]	...
Distillate test: Distillate, volume percent of total distillate to 360 °C [680 °F]:										
to 225 °C (437 °F)	...	35	...	25	...	20	...	...	...	...
to 260 °C [500 °F]	30	75	10	70	5	55	...	40	...	15
to 316 °C [600 °F]	75	95	65	93	60	90	45	85	15	75
Residue from distillation to 360 °C [680 °F], percent volume by difference	50	...	55	...	67	...	75	...	80	...
Tests on residue from distillation:										
Viscosity at 60°C [140°F], Pa-s ^A	30	120	30	120	30	120	30	120	30	120
Ductility at 25°C [77°F], cm	100	...	100	...	100	...	100	...	100	...
Solubility, %	99.0	...	99.0	...	99.0	...	99.0	...	99.0	...
Water, %	...	0.2	...	0.2	...	0.2	...	0.2	...	0.2

^A Instead of viscosity of the residue, the specifying agency, at its option, can specify penetration 100 g: 5s at 25 °C [77 °F] of 120 to 300 for Grades MC-30, MC-70, MC-250, and 120 to 250 for MC-800 and MC-3000. However, in no case will both be required.

Slow Curing (SC) Cut-Back Bitumen:

ASTM D2026 shall be adopted as the standard specification for slow curing cutback bitumen. Following Table will be utilized to identify different grades of Slow Curing Cutback Bitumen. However, Slow Curing Cutback shall not be used in general pavement application, except highly specialized usage with proper permission of Engineer in charge.

Table 3.7-7: ASTM D2026 Specification for Slow Curing Cutback Bitumen

Requirements for Cutback Asphalt (Slow-Curing Type)								
Note 1-If the ductility at 25°C [77°F] is less than 100, the material will be acceptable if its ductility at 15°C [59°F] is more than 100.								
Designation	SC-70		SC-250		SC-800		SC-3000	
	Min	Max	Min	Max	Min	Max	Min	Max
Kinematic viscosity at 60°C [140°F], mm ² /s	70	140	250	500	800	1600	3000	6000
Flash point (Cleveland open cup), °C (°F)	66 [150]	...	79 [175]	...	93 [200]	...	107 [225]	...
Distillation test:								
Total distillate to 360°C (680°F), volume %	10	30	4	20	2	12	...	5
Solubility, %	99.0	...	99.0	...	99.0	...	99.0	...
Kinematic viscosity on distillation residue at 60°C [140°F], mm ² /s	400	7000	800	10000	2000	16000	4000	35000
Asphalt residue:								
Residue of 100 penetration, %	50	...	60	...	70	...	80	...
Ductility of 100 penetration residue at 25°C [77°F], cm	100	...	100	...	100	...	100	...
Water, %	...	0.5	...	0.5	...	0.5	...	0.5

Following ASTM Test methods should be used for measurement of properties as stated above.

1. D5 Test Method for Penetration of Bituminous Materials
2. D95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation
3. D113 Test Method for Ductility of Bituminous Materials
4. D140 Practice for Sampling Bituminous Materials
5. D402 Test Method for Distillation of Cutback Asphalt
6. D2042 Test Method for Solubility of Asphalt Materials in Trichloroethylene

7. D2170 Test Method for Kinematic Viscosity of Asphalts (Bitumens)
8. D2171 Test Method for Viscosity of Asphalts by Vacuum Capillary Viscometer
9. D3143 Test Method for Flash Point of Cutback Asphalt with Tag Open-Cup Apparatus
10. D7553 Test Method for Solubility of Asphalt Materials in N-Propyl Bromide

3.7.2.1.6 Emulsified Bitumen:

Catanionic and anionic emulsion can be used. Tests performed to exhibit adherence to specification is valid for 14 days. Depending on the setting tendency and emulsifier charge, following classifications can be used for emulsions:

Cationic Emulsion:

ASTM D2397 specification will be followed for categorization of Cationic Emulsified Asphalt.

Table 3.7-8: ASTM D2397 Specification for cationic Emulsified Bitumen

Requirements for Cationic Emulsified Asphalt														
Now 1-CQS-1h emulsions shall meet the requirements outlined in Practices D3910.														
Nom 2-CQS-1h is used for quick-set slurry seal systems.														
Note 3-For viscosity, specify either Test Method D7226 or D7496.														
Non-4-Specify either ash content (Test Method D8078) or solubility (Test Method D2042 or D7553).														
	Rapid-Setting				Medium Setting				Slow Setting				Quick Setting	
Type	CRS-1		CRS-2		CMS-2		CMS-2h		CSS-1		CSS-1h		COS-1h	
Grade	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Tests on Emulsified Asphalts														
Viscosity, SayboltFurol at 25 °C [77 °F] SFS									20	100	20	100	20	100
Viscosity, SayboltFurol at 50 °C [122 °F] SFS	20	100	100	400	50	450	50	450						
Viscosity, Rotational Paddle Viscometer at 25 °C [77 °F] mPa s									45	220	45	220	45	220
Viscosity, Rotational Paddle Viscometer at 50 °C [122 °F] mPa s	45	220	220	880	110	990	110	990						
Storage stability test, 24 h, % ^A		1		1		1		1		1		1		
Demulsibility, 35 ml, 0.8 % dioctyl sodium sulfosuccinate, %	40		40											
Coating ability and water resistance:														
Coating, dry aggregate					good		good							
Coating, after spraying					fair		fair							
Coating, wet aggregate					fair		fair							
Coating, after spraying					fair		fair							
Particle charge test	positive		positive		positive		positive		positive		positive		positive	
Sieve test, %		0.10		0.10		0.10		0.10		0.10		0.10		0.10
Cement mixing test, %										2.0		2.0		N/A
Distillation:														
Oil distillate, by volume of emulsion, %		3		3		12		12						
Residue, %	60		65		65		65		57		57		57	
Tests on Residue from Distillation Test														
Penetration, 25 °C [77 °F], 100 g, 5 s	100	250	100	250	100	250	40	90	100	250	40	90	40	90
Ductility, 25 °C [77 °F], 5 cm/min, cm	40		40		40		40		40		40		40	
Ash content, %	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0
Solubility in trichloroethylene, %	97.5		97.5		97.5		97.5		97.5		97.5		97.5	

^A This test requirement on representative samples is waived if successful application of the material has been achieved in the field.

Following ASTM Test methods should be used for measurement of properties as stated above.

1. D5/D5M Test Method for Penetration of Bituminous Materials
2. D113 Test Method for Ductility of Asphalt Materials
3. D140/D140M Practice for Sampling Asphalt Materials
4. D244 Test Methods and Practices for Emulsified Asphalts
5. D2042 Test Method for Solubility of Asphalt Materials in Trichloroethylene
6. D3910 Practices for Design, Testing, and Construction of Slurry Seal
7. D6930 Test Method for Settlement and Storage Stability of Emulsified Asphalts
8. D6933 Test Method for Oversized Particles in Emulsified Asphalts (Sieve Test)
9. D6935 Test Method for Determining Cement Mixing of Emulsified Asphalt
10. D6936 Test Method for Determining Demulsibility of Emulsified Asphalt
11. D6997 Test Method for Distillation of Emulsified Asphalt
12. D7226 Test Method for Determining the Viscosity of Emulsified Asphalts Using
a Rotational Paddle Viscometer
13. D7402 Practice for Identifying Cationic Emulsified Asphalts
14. D7496 Test Method for Viscosity of Emulsified Asphalt by SayboltFurool
Viscometer
15. D7553 Test Method for Solubility of Asphalt Materials in N-Propyl Bromide
16. D8078 Test Method for Ash Content of Asphalt and Emulsified Asphalt Residues

Anionic Emulsion:

ASTM D977 specification will be followed for categorization of Anionic Emulsified Bitumen as shown in the following table.

Table3.7- 9: ASTM D2028 Specification for Anionic Emulsified Bitumen

TABLE 1 Requirements for Emulsified Asphalt												
Nors 1-QS-Th emulsions shall meet the requirements outlined in Practices D3910.												
Nom 2-QS-1h is used for quick-set slurry seal systems.												
Note 3-For viscosity, specify either Test Method D7226 or D7496.												
Non 4-Specify either ash content (Test Method D8078) or solubility tests (Test Method D2042 or D7553)												
Type	Rapid-Setting						Medium Setting					
	RS-1		RS-2		HFRS-2		MS-1		MS-2		MS-2h	
Grade	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Tests on Emulated Asphalts												
Viscosity, SayboltFurol at 25 °C SFS	20	100	...	...	...	...	20	100	100	...	100	...
Viscosity, SayboltFurol at 50 °C SFS	...	...	75	400	75	400	...	...	...	...	...	...
Viscosity, Rotational Paddle at 25 °C, mPa s	45	220	...	...	...	...	45	220	220	...	220	...
Viscosity, Rotational Padde at 50 °C, mPa s	...	...	165	880	165	880	...	...	...	...	...	...
Storage stability test, 24 % ^A	...	1	...	1	...	1	...	1	...	...	...	1
Demulsibily 35 ml, 0.02 N CaCl ₂ %	60	...	60	...	60	...	...	...	...	...	...	...
Coating ability and water resistance												
Coating, dry aggregate	...	...	...	...	...	...	good	good	good	good	good	good
Coating, after spraying	...	...	...	...	...	...	fair	fair	fair	fair	fair	fair
Coating, wet aggregate	...	...	...	...	...	...	fair	fair	fair	fair	fair	fair
Coating, after praying	...	...	...	...	...	...	fair	fair	fair	fair	fair	fair
Cement mixing test, s	...	...	...	...	...	...	...	...	...	...	...	...
Sieve test%	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10
Residue by disation %	55	...	63	...	63	...	55	...	65	...	65	...
Oil distillate by volume of emulsion, %	...	...	...	...	...	...	...	...	...	...	...	...
Tests on Residue from Distillation Test												
Penetration, 25 °C, 100 g, 5 s	100	200	100	200	100	200	100	200	100	200	40	90
Ductility, 25 °C, 5 amimin, cm	40	...	40	...	40	...	40	...	40	...	40	...
Solubility in trichloroethylene or n-propyl bromide, %	97.5	...	97.5	...	97.5	...	97.5	...	97.5	...	97.5	...
Ash content, %	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0
Float test, 60 °C s	...	...	...	...	1200	...	...	...	...	...	...	...

Type	Medium Setting								Slow-Setting				Quick Setting	
	HFMS-1		HFMS-2		HFMS-2h		HFMS-2s		SS-1		SS-1h		OS-1h	
Grade	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Tests on Emulated Asphalts														
Viscosity, Saybolt Furol at 25 °C SFS	20	100	100	...	100	...	50	...	20	100	20	100	20	100
Viscosity, Saybolt Furol at 50 °C SFS	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Viscosity, Rotational Paddle at 25 °C, mPa s	45	220	220	...	220	...	110	...	45	220	45	220	45	220
Viscosity, Rotational Padde at 50 °C, mPa s	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Storage stability test, 24 h, % ^A	...	1	...	1	...	1	...	1	...	1	...	1	...	...
Demulsibility, 35 m, 0.02 N CaCl ₂ , %	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Coating ability and water resistance:														
Coating, dry aggregate	good	good	good	good	good	good	good	good	...	...	...	...	...	...
Coating, after spraying	fair	fair	fair	fair	fair	fair	fair	fair	...	...	...	...	...	...
Coating, wet aggregate	fair	fair	fair	fair	fair	fair	fair	fair	...	...	...	...	...	...
Coating, after spraying	fair	fair	fair	fair	fair	fair	fair	fair	...	...	...	...	...	...
Cement mixing test, %	...	...	...	...	...	...	...	...	...	2.0	...	2.0	...	N/A
Seve test, % ^A	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10
Residue by distillation, %	55	...	65	...	65	...	65	...	57	...	57	...	57	...
Oil distillate by volume of emulsion	...	...	...	...	...	...	1	7	...	...	...	...	...	...
Tests on Residue from Distillation Test:														
Penetration, 25 °C, 100 g, 5 s	100	200	100	200	40	90	200	...	100	200	40	90	40	90
Ductility, 25 °C, 5 cm/min, cm	40	...	40	...	40	...	40	...	40	...	40	...	40	...
Solubility in trichloroethylene or n-propyl bromide %	97.5	...	97.5	...	97.5	...	97.5	...	97.5	...	97.5	...	97.5	...
Ash content, %	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0
Float test, 60 °C s	1200	...	1200	...	1200	...	1200	...	...	...	...	...	...	...

^A This test requirement on representative samples is waived if successful application of the material has been achieved in the field

Following ASTM Test methods should be used for measurement of properties as stated above.

1. D5/D5M Test Method for Penetration of Bituminous Materials
2. D113 Test Method for Ductility of Asphalt Materials
3. D139 Test Method for Float Test for Bituminous Materials
4. D140/D140M Practice for Sampling Asphalt Materials
5. D244 Test Methods and Practices for Emulsified Asphalts
6. D2042 Test Method for Solubility of Asphalt Materials in Trichloroethylene
7. D3910 Practices for Design, Testing, and Construction of Slurry Seal
8. D6930 Test Method for Settlement and Storage Stability of Emulsified Asphalts
9. D6933 Test Method for Oversized Particles in Emulsified Asphalts (Sieve Test)
10. D6935 Test Method for Determining Cement Mixing of Emulsified Asphalt
11. D6936 Test Method for Determining Demulsibility of Emulsified Asphalt
12. D6997 Test Method for Distillation of Emulsified Asphalt
13. D7226 Test Method for Determining the Viscosity of Emulsified Asphalts Using a Rotational Paddle Viscometer
14. D7496 Test Method for Viscosity of Emulsified Asphalt by SayboltFurol Viscometer
15. D7553 Test Method for Solubility of Asphalt Materials in N-Propyl Bromide
16. D8078 Test Method for Ash Content of Asphalt and Emulsified Asphalt

3.7.3 Methods of Storage, Handling and Application

Bituminous materials shall be handled and stored with due regard for safety and in such a way that at the time of use in the work the materials conform to the Specifications. In particular, bitumen emulsion shall be handled with care and not subjected to mechanical shocks or extremes of temperature likely to cause separation of the bitumen. Bitumen emulsion showing signs of separation shall not be used. The bitumen shall be applied at the temperature range called for in Table 3.4-6 for the particular material being used.

Table 3.7-10 Spraying Temperatures for Bitumen

Type	Grade	Temperature (°C)
Cut + Backs R.C. Or M.C	30	38-57
	70	57-71
	250	77-94
	800	99-113
	3000	118-132
Penetration Grade Bitumen	60-70	151-161
	80-100	151-161
	200-300	138-151
Emulsion: As necessary for uniform spraying and satisfactory penetration		

3.8 GENERAL REQUIREMENTS FOR BITUMEN BOUND SURFACING (PLANT METHOD)

3.8.1 Description

3.8.1.1 General

This work shall cover the general requirements that are applicable to all types of bituminous bound surfacing irrespective of gradation of mineral aggregate, kind and amount of bituminous material, or use. Deviations from these general requirements are indicated in the specific requirements as set forth in the respective Sections of the Specifications.

Section 3.9 is for Prime Coats

Section 3.10 is for Tack Coats

Section 3.11 is for Primer Seal

Section 3.12 is for Bituminous Surface Treatment (Plant Method).

Section 3.13 is for Dense Bituminous Surfacing (Plant Method).

Section 3.14 is for Polymer modified Bitumen (PMB).

Section 3.15 is for Bituminous Carpeting (Plant Method).

Section 3.16 is for Premix Bituminous Seal Coat (Manual Method).

The work shall consist of one or more courses of pre-mixed bituminous mixtures constructed on a prepared and accepted base course or other roadbed in accordance with Sections of these Specifications and in conformity with the required lines, levels, grades, dimensions and typical cross sections.

3.8.1.2 General Composition of Mixtures

The bituminous mix shall be composed basically of coarse mineral aggregate, fine mineral aggregate, filler, and bituminous material. The several mineral constituents shall be sized, uniformly graded, and combined in such proportions that the resulting blend meets the grading requirements for the specific type under the Contract. To such composite blended aggregate shall be added bitumen within the percentage limits set in the specifications for the specific type.

3.8.1.3 Formula for Job-Mix

Before starting work, the Contractor shall submit in writing to the Engineer a job-mix formula for each type of proposed asphaltic mixture. This shall state the sources and types of the various materials to be used, the mixing proportions of the various constituents, the method of mixing, the methods of heating bitumen and aggregates (including means of temperature control) and the means of transportation, laying and compaction. The formula so submitted shall stipulate a single definite temperature for the emptying of the mixture from the mixer, and, for mixtures to be laid hot, a single definite temperature at which the mixture is to be delivered on the road, all of which shall fall within the ranges of the general composition and temperature limits. The job-mix formula for the mixture shall indicate the percentage of aggregate passing each required sieve size and the percentage of bitumen to be added to the aggregate.

The contractor shall not commence bituminous surfacing work until the job mix formula has been approved in writing by the Engineer, including any adjustments to the job mix formula which the Engineer considers are necessary.

Following approval of the mix formulae the Contractor shall produce trial mixes and lay trial sections of surfacing for each formula. As many samples of the materials shall be taken and tested as the Engineer considers necessary for checking the required uniformity of the mixture and ensuring compliance with the Specification. Following approval of the trial sections by the Engineer in writing the actual surfacing works may be carried out strictly in accordance with the approved mix formulae and trial sections.

Should a change in a material be encountered or should a change in a source of material be made, a new mix formula shall be submitted and approved before the mixture containing the new material is delivered for trials and approval on the surfacing works.

3.8.1.4 Applications of Job-Mix Formula and Allowable Tolerances

All mixture furnished shall conform to the job-mix formula, within the ranges of tolerance given below and subject to the maximum temperatures as given in clauses 3.13.3.2, 3.13.3.4 and Table 3.8-3: -

Passing sieves 10 mm and larger	± 8%
Passing sieves between 10 mm and 0.075 mm	± 4%
Passing 0.075 mm sieve	± 1%
Bitumen content (single test result).....	± 0.40%
Bitumen content (three consecutive test results).....	± 0.30%
Temperature of mixture when emptied from mixer	± 6° C
Temperature of mixture at delivery on road.....	± 6° C

These tolerances are applicable to individual test results. The mean value for a series of test results should be as close as possible to the approved job mix formula. The grading shall not be allowed to vary from coarser side on one sieve to finer side on another sieve within the approved job mix grading envelope.

Each day as many samples of the materials and mixture shall be taken and tested as the Engineer considers necessary for checking the required uniformity of the mixture. When unsatisfactory results are obtained the Contractor should take immediate corrective action. If the Engineer is not satisfied with the actions taken he may halt production, which will not be allowed to resume until the Contractor demonstrates that the problem has been corrected.

Job materials will be rejected if they are found not to conform to the requirements of the Specification.

3.8.2 Materials

3.8.2.1 Coarse Mineral Aggregate

The portion of the aggregate retained on the 5 mm sieve shall be known as coarse aggregate and shall be crushed stone, or crushed gravel. Only one source of coarse aggregate shall be used except by written permission from the Engineer. Approval of sources of supply of aggregate shall be obtained from the Engineer prior to delivery of the material. Samples and test results shall be submitted for approval of the Engineer at least 14 days in advance of its use.

Crushed stone and crushed gravel shall consist of clean, tough, durable material free from coherent coatings, decomposed stone, soft particles, organic matter, shale, clay and any other substances, which in the opinion of the Engineer may be deleterious to the mixture. Coarse aggregate shall meet the following requirements.

Table 3.8-1: Requirements for Coarse Mineral Aggregate

S.No.	Name of Test	Wearing Course	Base Course	Test Procedure
1	Aggregate Impact Value (AIV) (%)	Less than 20%	Less than 20%	BS 812-112
2	Los Angeles Abrasion (LAA) (%)	Less than 25%	Less than 25%	AASHTO T96
3	Water absorption	Not more than 2%	Not more than 2%	STP 7.5.4
4	Soundness	Loss in weight (after 5 cycles) with Sodium Sulphate solution- not more than 10%		AASHTO T104
5	Coating & Stripping Test	Min. 95% retained coating		AASHTO T182
6	Boiling water Test			ASTM D3625/3626
7	Moisture Sensitivity Test	Ratio of dry ITS to Wet ITS > 80%		AASHTO T 283

**Flat and Elongated criteria apply to coarse aggregate larger than #4 sieve(4.75mm)*

When crushed gravel is used, not less than 95% by weight of the particles retained on a 5 mm sieve shall have at least two fractured faces.

The flakiness index as determined in accordance with STP 7.3.1 shall not exceed 15%.

3.8.2.2 Fine Mineral Aggregate

The portion of the aggregate passing a 5 mm sieve shall be known as fine mineral aggregate, and shall consist of natural sand, stone screenings, or a combination of both. Stone screenings shall be produced from stone meeting the requirements for coarse mineral aggregate in Section 3.8.2.1. Fine aggregate shall be composed of clean, hard durable particles, rough surfaced and angular, free from vegetable matter, soft particles, clay balls or other objectionable material.

The PI for material passing the 0.425 mm sieve shall be less than 4. Sand Equivalent of material passing 4.75 mm sieve, when tested in accordance with AASHTO T176, shall be minimum 50.

When the fine aggregate is tested for soundness as per AASHTO T104, the loss in weight after 5 cycles with sodium sulphate shall not exceed 15%. Fine Aggregate Angularity (AASHTO T304-96 ;2000) shall be minimum 45%. This property ensures a high degree of fine aggregate internal friction and rutting resistance.

Approval of sources of supply of aggregate shall be obtained from the Engineer prior to delivery of the material. Samples and test results shall be submitted for approval of the Engineer at least 14 days in advance of its use.

3.8.2.3 Mineral Filler

Mineral filler where required shall consist of limestone dust, dolomite dust, or similar rock dust, Portland cement, hydrated lime, silica cement or other mineral matter from

sources approved by the Engineer. Cement is preferable. It shall be non-plastic and free from foreign or other objectionable material. It shall be dry and free from lumps and when tested by means of laboratory sieves shall meet the following grading requirements:

Table 3.8-2: Requirements for Mineral Filler

Sieve Designation	Percentage by Weight (STP 3.3)
0.600 mm	100
0.150 mm	95 – 100
0.075 mm	65 – 100

3.8.2.4 Bituminous Materials

Details as to the source and type of bitumen must be submitted for approval at least 14 days before the proposed use of the material and should conform to the requirements of Section 3.7. The Engineer may instruct for samples of the bitumen to be taken from the consignment before leaving the place of manufacture and that these should be forwarded to a laboratory nominated by the Engineer for analysis and testing. The material from which these samples for testing are taken must be segregated at the place of manufacture until the satisfactory completion of the aforesaid tests permit release.

Each consignment of bituminous material delivered to the site must be accompanied by a certificate showing the place of manufacture and the results of standard tests carried out on the bulk supply from which the material was extracted. No bituminous material other than that represented by the sample submitted shall be used by the Contractor except with the written consent of the Engineer. The contractor shall, in accordance with Specification Clause 1.3.2 and when so directed by the Engineer, arrange for sampling and testing, at an approved testing laboratory, of all bituminous materials delivered to and stored at site. Blending of bituminous materials from different refineries shall not be permitted.

The Temperature for mixing, laying and compacting the bituminous mixing are given in Table 3.8-3

Table 3.8-3: Temperature Control

Serial No.	Description	Paving with Penetration Grade Bitumen	Paving with Modified Bitumen
01	Bitumen heated in plant	135 – 160 °C	150 – 180 °C
02	Aggregate heated in plant	150 – 165°C	135 – 220 °C
03	Mix delivered from plant	130 – 170 °C	145 – 180 °C
04	Mix delivered at site	125 – 160 °C	130 – 177°C
05	Initial Compaction	Min 125 °C	Min 140 °C
06	Intermediate Compaction	100 – 125 °C	115 – 140 °C
07	Final Compaction	Min 90 °C	Min 105 °C

3.8.3 Construction

3.8.3.1 Weather Limitation

Bituminous mixtures shall be placed only when the surface is dry, when rain does not appear imminent and when the prepared roadbed is in a satisfactory condition. However, the Engineer may permit, in case of sudden rain, the placing of mixture then in transit from the plant, if laid at proper temperature and if the roadbed is free from pools of water. Such permission shall in no way relax the requirements for quality and smoothness of surface.

3.8.3.2 Progress of Work

No work shall be performed when there is insufficient hauling, spreading or finishing equipment, or labour, to ensure progress at a rate not less than 75% of the capacity of the mixing plant.

3.8.3.3 Plant and Equipment

A) Requirements for all Mixing Plants

All plant used by the Contractor for the preparation of bituminous mixtures shall conform to all of the requirements below, except that scale requirements shall apply only where weight proportioning is used; and in addition, any batch mixing plants shall conform only to the relevant special requirements herein and any continuous mixing plants shall conform only to the relevant special requirements herein.

The mixing plant, which shall be a batching plant shall have a capacity sufficient to supply the paver on the road continuously when spreading the bituminous mix at normal speed and required thickness.

- 1) Uniformity- The plants shall be so designed, co-ordinated and operated as to produce a mixture within the job - mix tolerances. The plant shall be calibrated from a suitable Institute.
- 2) Plant scales and weigh house- Scales for any weigh box or hopper may be either of the beam or spring less dial type and shall be of a standard make and design accurate to within one-half of 1 percent of the maximum load required.

Scales shall be calibrated and approved by the Engineer and shall be checked as often as the Engineer may deem necessary to ensure their continued accuracy.

The Contractor shall provide and have at hand not less than ten 25 kilogram weights for frequent testing of all scales.

- 3) Equipment for preparation of bituminous material- Tanks for storage of bituminous material shall be capable of heating the material under effective and positive control at all times, to a temperature within the range specified. The circulating system for the bituminous material shall be of adequate size to ensure proper and continuous circulation during the entire operating period. Suitable means shall be provided for maintaining the specified temperature of the bituminous material in the pipe lines, meters, weigh buckets, spray bars, and

other containers or flow lines. The storage tank capacity shall be sufficient for at least 1 day's run. Bituminous material may be partially heated in the tanks and brought to the specified temperature by means of booster heating equipment between the tanks and the mixer.

- 4) Feeder for drier- The plant shall be provided with an accurate mechanical means for uniformly feeding the mineral aggregate into the drier so that uniform production and uniform temperatures are obtainable.
- 5) Drier- A rotary drier of approved design for drying and heating the mineral aggregate shall be provided. The drier shall be capable of drying and heating the mineral aggregate to the specified temperature.
- 6) Screens- Plant screens, capable of screening all aggregate to the specified sizes and proportions and having normal capacities slightly in excess of the full capacity of the mixer, shall be provided. The screens shall be readily exposed for inspection by the Engineer.
- 7) Bins- The plant shall include storage bins of sufficient capacity to supply the mixer when it is operating at full capacity. Bins shall be divided into at least three compartments and shall be arranged to ensure separate and adequate storage of appropriate fractions of the aggregate. For a mineral filler admixture a separate feeder bin and/or weighing hopper arrangement may be required. Bins shall be so constructed that representative samples can readily be obtained, and the aggregate level observed.
- 8) Bituminous control unit- Satisfactory means either by weighing or metering shall be provided to obtain the proper amount of bituminous material in the mix within the tolerance specified for the job-mix.

For use with batching plants, it shall provide the designated quantity of bituminous material for each batch. For continuous mixing plants, the operating speed of the pump shall be synchronised with the flow of aggregate in the mixer by an automatic locking control, and the device shall be easily and accurately adjustable. Means shall be provided for checking the quantity or rate of flow of bituminous material into the mixer. An accuracy within 1% of the specified amount is required.

- 9) Thermometric equipment- An armoured thermometer reading from 50°C to 200°C shall be fixed in the bituminous feed line at a suitable location near the discharge valve at the mixer unit.

The plant shall be further equipped with a thermometric instrument so placed at the discharge chute of the drier as to register automatically or indicate the temperature of the heated aggregate.

- 10) Dust collector- The plant shall be equipped with a dust collector constructed to waste or return uniformly to the elevator all or any part of the material collected. The material to be returned from the dust collector shall be weighed over the filler scale.

- 11) Control of mixing time- The plant shall be equipped with accurate positive means to govern the time of mixing and to maintain it constant unless changed at the direction of the Engineer. The time of mixing shall be considered as the interval between the time the bituminous material is spread on the aggregate and the time the same aggregate leaves the mixing unit.

When bitumen is applied by a spray system, the mixing time shall begin with the start of the bitumen spray. When the bitumen is not applied by a spray system, a minimum dry mixing period of five seconds shall precede the addition of the bitumen to the mix.

- 12) Safety requirements- Adequate and safe stairways to the mixer platform and guarded ladders to other plant units shall be placed at all points required for accessibility to all plant operations. All gears, pulleys, chains, sprockets, and other dangerous moving parts shall be thoroughly guarded and protected. Ample and unobstructed space shall be provided on the mixing platform. A clear and unobstructed passage shall be maintained at all times in and around the truck loading space. This space shall be kept free from drippings from the mixing platform. Flexible pipe connections carrying hot bitumen shall be shielded.

B) Special Requirements for Batch Mix Plants

- 1) Weigh box or hopper- The equipment shall include a means for accurately weighing each bin size of aggregate in a weigh box or hopper, suspended on scales, ample in size to hold a full batch without hand raking or running over. The weigh box or hopper shall be supported on fulcrums and knife edges so constructed that they will not easily be thrown out of alignment or adjustment. All edges, ends, and sides of weighing hoppers shall be free from contact with any supporting rods, columns or other equipment that will in any way affect the proper functioning of the hopper. There shall also be sufficient clearance between hoppers and supporting devices to prevent accumulations of foreign materials. The discharge gate of the weigh box shall be so hung that the aggregates will not be segregated when dumped into the mixer and shall close tightly when the hopper is empty so that no material is allowed to leak into the batch in the mixer during the process of weighing the next batch.
- 2) Mixer- The batch mixer shall be capable of producing a continuous uniform mixture within the job - mix tolerances. It shall be of such design as to permit visual inspection of the mix.

The mixer shall be equipped with a sufficient number of paddles or blades with proper arrangement to produce a properly and uniformly mixed batch. The clearance of blades from all fixed and moving parts shall not exceed 20 mm unless the maximum diameter of the aggregate particle in the mix exceeds 25 mm.

C) Special Requirements for Continuous Plants

- 1) Gradation control unit- The plant shall include a means for proportioning accurately each bin size of aggregate either by weighing or by volumetric measurement.

When gradation control is by volume, the unit shall include a feeder mounted under the compartment bins. Each bin shall have an accurately controlled individual gate to form an orifice for volumetrically measuring the materials drawn from each respective bin compartment. Indicators shall be provided for each gate to show the respective gate opening in centimetres.

- 2) Weight calibration of aggregate feed- The plant shall include provision for a calibration of the gate openings by means of weight test samples so that each of the materials fed out of the bins through individual orifices may be by-passed satisfactorily to suitable test boxes, each bin material being confined separately.

The plant shall be equipped to handle conveniently such test samples weighing not less than 150 kilograms combined weight of samples from all bins, and not less than 50 kilograms for any one bin sample.

- 3) Synchronisation of aggregate and bitumen feed- Satisfactory means shall be provided to afford positive interlocking control between the flow of aggregate from the bins and the flow of bitumen from the meter or other proportioning source. This control shall be accomplished by interlocking mechanical means or by a positive method satisfactory to the Engineer.

- 4) Mixer- The plant shall include a continuous mixer of an approved type capable of producing a continuous uniform mixture within the job - mix tolerances.

Determination of the mixing time shall be by a weight method, using the following formula (the weights shall be determined for the job): -

$$\text{Mixing time in seconds} = \frac{\text{Pugmill dead capacity in kilograms}}{\text{Pugmill output in kilograms per second}}$$

- 5) Hopper- The mixer shall be equipped with a hopper at the discharge end, of such size and design that no segregation of mix occurs. Any elevator used for loading mixture into vehicles shall have an equally satisfactory hopper.

D) Equipment for Hauling and Placing

- 1) Trucks- Trucks for hauling bituminous mixtures shall have tight, clean and smooth metal beds that have been sprayed with soapy water, thinned fuel oil, paraffin oil, or lime solution to prevent the mixture from adhering to the beds. The amount of sprayed fluid shall however be kept to the practical minimum. Each load shall be covered with canvas or other suitable material of such size as to protect the mixture from the weather. Any truck causing excessive segregation of material by its spring suspension or other contributing factors, or that shows

oil leaks in detrimental amounts, or that causes undue delays, shall upon direction of the Engineer be removed from the Works until such conditions are corrected. When necessary, in order that the mixture shall be delivered on the road at the specified temperature, truck beds shall be insulated to maintain workable temperature of the mixture and all covers shall be securely fastened.

Trucks or any other equipment leaking petroleum products will not be allowed admittance to paved areas or areas where paving is under construction.

- 2) Spreading and finishing equipment- The equipment for spreading and finishing shall be approved mechanical, self-powered pavers, capable of spreading and finishing the mixture true to the lines, grades, levels dimensions and cross sections.

The pavers shall be equipped with hoppers and distributing screws of the reversing type to place the mixture evenly in front of adjustable screeding devices and shall have reverse as well as forward travelling speeds.

The pavers shall maintain the grade and confine the edges of the pavement to true lines without the use of stationary side forms. The equipment shall include blending or joint levelling devices for smoothing and adjusting longitudinal joints between lanes. The assembly shall be adjustable to give the cross-section shape prescribed and shall be so designed and operated as to place the thickness or weight per square metre of material required.

Pavers shall be equipped with activated screeds and devices for heating the screeds to the temperature required for the laying of the mixture without pulling or marring.

The term “screed” includes any cutting, crowding, or other practical action that is effective in producing a finished surface of the evenness and texture specified, without tearing, shoving, or gouging.

If, during construction, it is found that the spreading and finishing equipment in operation leaves in the pavement surface tracks or indented areas of other objectionable irregularities that are not satisfactorily corrected by scheduled operations, the use of such equipment shall be discontinued and other satisfactory spreading and finishing equipment shall be provided by the Contractor forthwith.

Rollers shall be pneumatic tyred rollers and smooth wheel rollers with or without vibration. The rolling procedure is described in Section 3.8.3.4.

- 3) Small tools. The Contractor shall provide suitable means for keeping all small tools clean and free from accumulation of bituminous material. He shall provide and have ready for use at all times enough tarpaulins or covers, as may be directed by the Engineer, for use in any emergency such as rain, chilling wind, or unavoidable delay, for the purpose of covering or protecting any material that may have been dumped and not spread.

The batching plants shall be calibrated by reputed third party organization or as directed by the Engineer. The calibration interval shall be six (06) months or certain ideal period which ever minimum. It shall be part of the quality assurance of product of the plant.

3.8.3.4 Preparation and Placing

A) Preparation of Existing Surface

Where local irregularities in an existing surface would otherwise result in a course more than 75 mm thick after compaction, the surface shall be brought to uniform contour by patching with a bituminous mixture to be approved by the Engineer, and thoroughly tamping or rolling until it conforms to the surrounding surface. The mixture used shall be the same as that specified for the next course, unless the size of the largest aggregate in the mixture precludes this when the Engineer will decide the mixture to be used.

Where the existing roadbed is broken or shows instability, the unstable material shall be removed and disposed of as directed by the Engineer and be replaced with the same mixture as specified for the next course, compacted to the standard and elevation of the adjacent surface.

The surface upon which the mixture is to be placed shall be swept thoroughly and cleaned of all loose dirt and other objectionable material immediately before spreading the mixture.

B) Preparation of Bituminous Material

The bituminous material shall be heated to the specified temperature in kettles or tanks so designed as to avoid local overheating and to provide a continuous supply of the bituminous material to the mixer at a uniform temperature at all times.

C) Preparation of Mineral Aggregate

The mineral aggregates for the mixture shall be dried and heated before being placed in the mixer. Flames used for drying and heating shall be adjusted properly to avoid adversely affecting the aggregate and to avoid forming a heavy coating of soot on the aggregate. The aggregates shall be heated to the temperature specified in the applicable Section.

The aggregates, immediately after heating, shall be screened into three or more fractions and conveyed into separate bins ready for combining and mixing with bituminous material. The fraction of aggregate deposited in any bin shall not contain more than 10% of material outside the specified size limits for that bin.

D) Preparation of Mixture

The dried mineral aggregates prepared as prescribed above, shall be combined in the amount of each fraction of aggregate required to meet the job-mix formula for the particular mixture. The bituminous material shall be measured or gauged and introduced into the mix in the amount determined in the job mix formula. The proper

amount of bituminous material shall be distributed over the mineral aggregate and the whole thoroughly mixed for a period of at least 30 seconds, or longer if necessary to produce a homogeneous mixture in which all particles of the mineral aggregate are coated uniformly. For a continuous mixing plant, the mixing time shall be determined from the formula in Section 3.8.3.3(C)(4) and may be regulated by fixing a minimum gauge in the mixer unit and/or by other mixing unit adjustment.

E) Transportation and Delivery of Mixture

The mixture shall be transported from the mixing plant to the point of use in vehicles conforming to the requirements of Section 3.8.3.3(D)(1). Loading and transporting shall be such that spreading, compaction and finishing shall all be carried out during daylight hours unless satisfactory illumination is provided by the Contractor.

F) Spreading and Finishing

Upon arrival at the point of use, the mixture shall be spread and struck off to the grade, elevation, and cross-section shape intended, either over the entire width using full width paver. In case full width paver is not available two pavers will be used simultaneously with a distance gap of 20 m to avoid longitudinal cold joint. Bituminous mixture pavers conforming to the requirements of Section 3.8.3.3(D)(2) shall be used for this purpose. The mixture shall be laid upon an approved surface and only when weather conditions are considered suitable by the Engineer.

In narrow base widening, deep or irregular sections, turn outs or driveways where it is impractical to spread and finish the mixture by use of a paver, the Contractor shall use approved spreading equipment or acceptable hand methods as directed by the Engineer.

On areas where in the opinion of the Engineer, the use of spreading equipment is considered impractical, the mixture shall be dumped on steel boards then spread, raked and luted by hand to provide the correct weight or uniform thickness of material without segregation. Mixture shall not be applied faster than can be properly handled and spread.

G) Compaction of Mixture

- 1) General. Immediately after the mixture has been spread and struck off, the surface shall be checked and any inequalities adjusted. The mixture shall then be thoroughly and uniformly compacted by rolling. Each course shall be rolled as soon after being placed as the material will support the roller without undue displacement or cracking.
- 2) Roller Requirements. With each paver, two steel wheeled tandem rollers and one pneumatic tyred roller will be required.

All rollers shall be self-propelled, capable of being reversed without backlash and equipped with power steering, dual controls allowing operation from either the right or left side, water tanks, sprinkler systems and coco-mats to ensure even wetting of

rolls or tyres. The Contractor shall supply to the Engineer for each type of roller a calibration chart showing the relation between depth of ballast and weight and giving the tare weight of the roller. Each roller shall be in good condition and worked by a competent and experienced operative.

Steel wheeled tandem rollers shall weigh not less than 8 metric tons and each tandem roller used for final compaction (finish rolling) shall have at least one roll capable of applying a minimum rolling pressure of 35 kilograms per centimetre of roll width.

Pneumatic tyre rollers shall be of an approved type having not less than seven wheels with smooth tread compactor tyres of equal size and construction capable of operating at inflation pressures up to 8.5 kg/cm². Wheels shall be equally spaced along both axle lines and arranged so that tyres on one axle line track midway between those on the other with an overlap. Each tyre shall be kept inflated to the specified operating pressure such that the pressure difference between any two tyres shall not exceed 0.35 kg/cm². Means shall be provided for checking and adjusting the tyre pressures on the job at all times. Each roller shall be so equipped that its total weight is adjustable by ballasting allowing the load per wheel to be varied from 1,500 to 2,500 kilograms. In operation, the tyre inflation pressure and the wheel load shall be adjusted, as required by the Engineer, to meet the requirements of each particular application. In general, the compaction of any course with a pneumatic tyre roller shall be accomplished with contact pressures as high as the material will support.

3) Procedure. Rolling of the mix shall consist of six separate operations as follows:

- transverse joint
- longitudinal joint
- edges
- initial or breakdown rolling
- second or intermediate rolling
- finish rolling

Prior to start of work, cold joint shall be cut vertically and tack shall be placed on vertical surface. The first rolling of all joints and edges, the initial or breakdown rolling and the final or finish rolling shall all be done with the steel wheeled tandem rollers.

The second or intermediate rolling shall be done with the pneumatic tyred roller except on small operations.

Rolling shall start longitudinally at the sides and proceed toward the centre of the pavement except that on super-elevated curves rolling shall begin at the low side and progress toward the high side. Successive trips of the roller shall overlap by at least one half of the width of the roller and alternative trips shall not terminate at the same point. For initial rolling, the drive roll should be nearest the paver.

The speed of the rollers shall not exceed 4 kilometres per hour for steel wheeled rollers and 6 kilometre per hour for pneumatic tyred rollers and shall at all times be slow enough to avoid displacement of the hot mixture. Any displacements occurring as a result of reversing the direction of the roller or from any other cause shall at once be corrected with rakes and fresh mixture where required. Care shall be exercised in rolling not to displace the line and grade of the edges.

Rolling shall progress continuously as may be necessary to obtain uniform compaction while the mixture is in a workable condition and until all roller marks are eliminated. Heavy equipment or rollers shall not be permitted to stand on the newly laid surface until it has thoroughly cooled.

To prevent adhesion of the mixture to the roller, the wheels shall be kept properly moistened, but excess water will not be permitted.

Any petroleum products dropped or spilled from the vehicles or equipment employed by the Contractor upon any portion of the pavement under construction is cause for the removal and replacement of the contaminated pavement by the Contractor.

Along kerbs, headers, manholes, and similar structures and at all places not accessible to the roller, thorough compaction shall be secured by means of hot hand tampers or with mechanical tampers giving equivalent compaction. Each hand tamper shall weigh not less than 10 kilograms and shall have a tamping face area of not more than 250 square centimetres.

The surface of the mixture after compaction shall be smooth and true to the established crown and grade within the tolerance specified. Any mixture that becomes loose and broken, mixed with dirt, or which is defective in any way, shall be removed and replaced with fresh hot mixture, which shall be compacted immediately to conform with the surrounding area. Any area of 1,000 square centimetres or more showing an excess or deficiency of bituminous material shall be removed and replaced. All high spots, high joints, depressions, and honeycombs shall be adjusted as directed by the Engineer.

H) Joints

Both longitudinal and transverse joints in successive courses shall be staggered so as not to be one above the other. Longitudinal joints shall be staggered a minimum of 30cm and so arranged that the longitudinal joint in the top course shall be at the location of the line dividing the traffic lanes. Lateral joints shall be staggered a minimum of 100cm centimetres and shall be straight.

Spreading shall be as nearly continuous as possible and rollers shall pass over the unprotected end of freshly laid mixture only when authorised by the Engineer. In all such cases provision shall be made for a properly bonded and sealed joint with the new surface for the full depth of the course as specified above.

Before placing mixtures against them, all contact surfaces of kerbs, gutters, headers, manholes etc. shall be given a thin uniform coating of hot bitumen and the joints

between these structures and the surface mixture shall be effectively sealed by the subsequent spreading, finishing and compaction operations.

When the wearing course is placed adjacent to kerbs to form a bitumen gutter it shall be sealed with bitumen for a distance of 30 centimetres from the kerb. The seal shall be evenly applied to the surface by means of hot irons or squeegees so that the surface voids are completely filled and no excess bitumen remains on the surface. The desired drainage pattern shall be maintained.

3.8.3.5 Surface Test of the Pavement

The finished surface of the pavement for both base (binder) and wearing courses shall not vary from the specified levels and grades by more than $\pm 5\text{mm}$. The surface shall be also tested by a crown template and 3 metre straight edge, furnished by the Contractor, applied respectively at right angles and parallel, to the centreline of the road. The Contractor shall designate some employees to use the template and straight edge under the direction of the Engineer in checking all surfaces. The crown template shall conform to the typical cross section shown on the Drawings.

The variation of the surface from the testing edge of the crown template and the straight edge between any two contacts with the surface shall not exceed 5 millimetres for both binder and wearing courses.

Tests for conformity with the specified crown and grade shall, when agreed by the Engineer, be made immediately after initial compaction and variations shall be corrected by removing or adding materials as may be necessary. Rolling shall then be continued as specified. After final rolling, the smoothness of the course shall be checked again and any irregularity of the surface exceeding the above limits and any areas defective in texture, compaction, or composition, shall be corrected as directed by the Engineer, including removal and replacement at the Contractor's expense if so, directed by the Engineer.

The average thickness of the compacted bituminous layer, as computed from 5 successive determinations for every 400 to 800 m^2 of pavement area, shall not be less than the specified thickness nor shall any particular point be thinner than 5mm less than the specified thickness. Any section of paving having thickness measurements outside these limits shall be rectified at the contractor's expense as directed by the Engineer, including where necessary removal and replacement. In case of removal and relaying of the pavement layer a minimum length of 50m shall be removed for its full width.

The edges of the pavement shall follow a smooth alignment and, where not bound by kerbs or other edgings, shall not deviate from the specified alignment by more than $\pm 20\text{mm}$. Any material laid out of alignment is to be corrected as directed by the Engineer. Excess material shall be cut off square after final rolling, and disposed of by the Contractor. Finished pavement surface shall be tested for IRI (if specified in the particular specification), the recommended values/ranges for IRI is 1.75 – 2 m/km.

3.8.3.6 Control and Testing

The Contractor shall supply qualified personnel to be in charge of the tests and controls required to ensure correct operation of the plant and the manufacture of a satisfactory product.

The Contractor shall keep a diary and maintain records of times, batch numbers, areas paved and other observations, and he shall follow such instructions as may be given by the Engineer in order to obtain the required quality of the bituminous bound material.

3.8.4 Measurement

All work prescribed above shall be measured and paid for as provided in the respective Sections for each type of pavement. The quantity measured and paid for shall always be the quantity ordered with any permitted excess, or the actual quantity used whichever is the less.

3.8.5 Payment

The work shall be paid for as provided in the respective Section for each type of bituminous layer.

3.9 BITUMINOUS PRIME COAT

3.9.1 Description

This work shall consist of the careful cleaning of the surface to be primed and furnishing and applying bituminous material in accordance with these Specifications to the area shown on the Drawings or as directed by the Engineer.

3.9.2 Materials

3.9.2.1 Bituminous Materials

Bituminous material shall be a MC 30 or MC 70 cut back bitumen and shall conform to the requirements of Section 3.7.2.1.5 The bituminous material shall be approved by the Engineer and may be by cutting back 80/100 penetration bitumen with kerosene in the ratio of 100 parts by volume of bitumen to 40 – 60 parts by volume of kerosene depending on the porosity of the surface.

3.9.2.2 Blotting Material

Blotting material shall be approved clean dry sand or stone screenings free from any cohesive materials or organic matter. Not more than 10 per cent of the sand shall be finer than the 75-micron sieve.

3.9.3 Construction Methods

3.9.3.1 Weather Limitations

Prime coat shall be applied at a time when the surface to be treated is dry or slightly damp, when the ambient temperature is above 13°C and rising, or above 16°C if falling, and when the weather is dry.

3.9.3.2 Equipment

The Engineer may approve Construction equipment and methods (including labour intensive methods) other than those specified hereinafter provided that the contractor can demonstrate his ability to carry out the work to a satisfactory standard using his proposed equipment and methods to the complete satisfaction of the Engineer. Such approval shall be in writing and may be withdrawn at any time if the work is found to be unsatisfactory in any respect.

The equipment used by the Contractor shall include, unless otherwise approved by the Engineer, a power brush, a pressure bituminous distributor, and, when necessary, equipment for heating bituminous material.

The distributor shall have pneumatic tyres and shall be so designed, equipped, maintained and operated that bituminous material at constant temperature may be applied uniformly on variable widths of surface up to 4 metres at readily determined and controlled rates of from 0.2 to 2.0 litres per square metre with uniform pressure, and with an allowable variation from any specified rate not to exceed 0.1 litre per square metre. Distribution equipment shall include an instrument for measuring the speed of travel accurately at low speeds, and the temperature of the contents of the tank.

The spray bar on the distributor shall be controlled by a man riding at the rear of the distributor in such a position that operation of all sprays is in his full view.

The tanks of distributors shall be fitted with accurately calibrated dipsticks or contents gauges.

All measuring equipment on the distributor shall have been recently calibrated and an accurate and satisfactory record of such calibration shall be supplied to the Engineer. If, after beginning the work, the distribution of bituminous material is found to be in error, the distributor shall be withdrawn from the work and calibrated to the satisfaction of the Engineer before any further work is undertaken.

The Engineer may require such tests, as he considers necessary to check the performance of the distributor. As and when directed by the Engineer, the Contractor, at his own expense, shall make the distributor and its equipment available for field testing and shall supply any assistance required for this purpose. Any distributor, which does not operate satisfactorily or conform to the requirements of the Specifications in all respects, may be rejected by the Engineer for further use on the Works.

3.9.3.3 Cleaning Surface

Immediately before applying the bituminous material, all loose dirt and other objectionable material shall be removed from the surface with a power brush. When so ordered by the Engineer, a light application of water shall be made just before the application of bituminous material.

3.9.3.4 Application of Bituminous Material

Bituminous material shall be applied at the rate, or rates, either shown in the Contract Documents or as directed by the Engineer. The rate sprayed can be verified using STP 10.12. This will usually be from 1.0 to 2.5 litres per square metre, and at a temperature within the range called for in Table 3.7-10 for the particular material being used. Any prescribed application shall be divided into two applications when necessary to prevent bitumen flowing off the surface, and additional bituminous material shall be applied where surface conditions indicate it to be necessary, if the Engineer so directs. No further courses shall be applied until the prime coat has dried and the solvent evaporated.

When so directed, the prime coat shall be applied in lanes of approximately one-half or less of the width of the completed surface. A lane of prime coat shall be applied, allowed to penetrate for not less than 48 hours, then covered with blotting material if required, and opened to traffic before bituminous material is applied to the adjacent lane. In covering the first primed lane, a strip at least 200 mm wide shall be left uncovered where it joins the second traffic lane to permit an overlap of the bituminous material.

The surface of structures and trees adjacent to the areas being treated shall be protected in such manner as to prevent their being splashed or damaged. No bituminous material shall be discharged into a borrow pit or gutter.

3.9.3.5 Maintenance and Opening to Traffic

Traffic shall not be permitted on the primed surface until the material has penetrated and dried and, in the opinion of the Engineer, will not be picked up by traffic. Where the Engineer deems it impracticable to detour traffic, the Contractor shall spread the minimum quantity as determined by the Engineer, of blotting material necessary to avoid picking up, and traffic shall be allowed to use areas so treated. Any areas containing an excess or deficiency of priming material shall be corrected by the addition of sand or bitumen as directed by the Engineer. Such corrections of faulty work shall be carried out at the Contractor's expense.

3.9.4 Measurement

The quantity of bituminous material shall be measured for payment in square metres; however, in the case of plant placed materials a record of the number of Litres of bituminous material placed will also be kept.

The measured quantity shall be the theoretical required to comply with the Contract, or shall be the quantity used and accepted. This should be within $\pm 5\%$ of the theoretical quantity unless there is a change in the area of coverage.

3.9.5 Payment

This work measured as provided above, shall be paid for at the Contract unit price per unit of measurement. The prices and payment shall be full compensation for preparation of the surface and furnishing and placing the materials and application of blotting materials including all labour, equipment, tools and incidentals necessary to complete the work prescribed in this Section.

Pay item shall be:

3/9/1(a)Bituminous Prime Coat (plant placed)	Square Metre
3/9/1(b)Bituminous Prime Coat (hand placed)	Square Metre

3.10 BITUMINOUS TACK COAT

3.10.1 Description

This work shall consist of furnishing and applying bituminous material to a previously prepared roadbed, in accordance with the Specifications and to the width and area required by the Engineer.

3.10.2 Materials

Bituminous material shall be either 60/70 or 80/100 penetration grade bitumen, cut back bitumen RC 30, RC 70, or rapid setting emulsion conforming to the requirements of Section 3.7.2.1 of these Specifications. The bituminous material shall be approved by the Engineer.

3.10.3 Construction Methods

3.10.3.1 Equipment

The Engineer may approve Construction equipment and methods (including labour intensive methods) other than those specified hereinafter provided that the contractor can demonstrate his ability to carry out the work to a satisfactory standard using his proposed equipment and methods to the complete satisfaction of the Engineer. Such approval shall be in writing and may be withdrawn at any time if the work is found to be unsatisfactory in any respect. The equipment shall be as specified in Section 3.9 Bituminous Prime Coat.

3.10.3.2 Cleaning Surface

The full width of surface to be treated shall be cleaned with a power brush to remove loose dirt, sand, dust and other objectionable material. The surface to be treated shall be dry.

3.10.3.3 Application of Bituminous Material

Immediately after cleaning the surface, bituminous material shall be applied at the rate directed by the Engineer, but not to exceed 0.45 litres per square metre and at the temperature within the range included in Table 3.7-10 for the particular material being used. The tack coat shall be applied only when the surface is dry.

The tack coat material shall be uniformly distributed over the surface without streaking. Quantities shall not deviate more than 10% from the quantity prescribed by the Engineer. Quantities outside the specified tolerances shall be adjusted by the Contractor at his own expense, to the satisfaction of the Engineer.

The surfaces of structures and trees adjacent to the areas being treated shall be protected in such manner as to prevent their being splashed or damaged. No bituminous material shall be discharged into a borrow pit or gutter. The Engineer may direct that emulsions shall be diluted with clean water in order to control the rate of spread. This shall be done at the Contractor's expense.

After the tack coat is applied the Contractor shall protect it from damage until the surface course is placed. No surfacing layer will be permitted to be placed unless the tack coat is in a satisfactory condition to receive it and as such the tack coat shall be applied only so far in advance of surface course placement as is necessary for this to occur.

3.10.4 Measurement

The quantity of bituminous material shall be measured for payment in square metres; however, in the case of plant placed materials a record of the number of Litres of bituminous material placed will also be kept.

The measured quantity shall be the theoretical required to comply with the Contract, or shall be the quantity used and accepted. This should be within $\pm 5\%$ of the theoretical quantity unless there is a change in the area of coverage.

3.10.5 Payment

This work measured as provided above, shall be paid for at the Contract price per unit of measurement. The prices and payment shall be full compensation for furnishing and placing the materials, including all labour, equipment, tools and incidental necessary to complete the work.

Pay item shall be:

3/10/1(a)Bituminous Tack Coat (plant work)	Square Metre
3/10/1(b)Bituminous Tack Coat (labour intensive work)	Square Metre

3.11 PRIMER SEAL

3.11.1 Description

The work shall consist of an application of bituminous material followed by spreading of pea-gravel, a cover coat material, in accordance with these Specifications to the area shown on the Drawings or as directed by the Engineer.

3.11.2 Materials

3.11.2.1 Bituminous Material

Cutback bitumen conforming to the requirements of section 3.7.2.1.5 as appropriate shall be used for the purpose. The 80-100 penetration grade bitumen may be converted into cutback by fluxing and thoroughly mixing 4% diesel with the bitumen after it is heated. The method of mixing or fluxing for cutback from 80-100 penetration grade bitumen shall be approved by the Engineer.

3.11.2.2 Cover Coat Material

Cover coat material used for this work shall be screened Pea gravel conforming to the Specification and graded so that 100% of the materials falls within the size range of 2.4 mm to 6.3 mm. Pea-gravel shall be washed by water, dried and be free from any organic matter, clay or any other objectionable matter and completely dust free. Samples of the Pea gravel proposed for use shall be submitted for approval of the Engineer.

3.11.3 Construction Methods

3.11.3.1 Cleaning Surface

The contractor shall furnish all labour and equipment required for thoroughly cleaning the surface to be primed. The cleaning shall be done in such a manner as to thoroughly remove all mud, dust and other foreign materials. The sweeping on a water bound surface shall be just sufficient to expose the pattern of the coarse aggregate. Any surplus bituminous materials shall be removed from the surface.

Special care shall be taken to clean the edges of the road to be primed in order to ensure uniform application of the bituminous materials, directly on the existing base of pavement material.

3.11.3.2 Applying Bituminous Materials

Primer seal work shall be carried out only when the surfaces and aggregates are dry and shall only be commenced in areas which can be completed in dry conditions. Any work which becomes wet by rain or other causes before rolling is completed may be rejected.

Fluxed bitumen, at a temperature as given in table 3.7-10, shall be applied uniformly to the prepared surface at a rate of 1.0 L/m² or as directed by the Engineer.

Application may be approved by labour intensive methods in which case the following procedure will be adopted.

- The surface to be sprayed will be marked into 1 meter wide strips for the full width of the pavement.
- Using a container constructed to hold the quantity of bituminous materials required for the area of 1 strip, apply the fluxed bitumen using a rubber squeegee.
- The contractor shall furnish a thermometer at each mixing unit to ensure that temperature of cutback bitumen is always within specified range.

3.11.3.3 Spreading and Rolling

Screened pea gravel aggregate, shall be spread uniformly to the required density over the bitumen prime as soon as possible after application of the bitumen to provide a dense uniform cover one stone thick. Brooming or other methods shall be

used if necessary to achieve a uniform spread rate. The aggregate application rate will be approximately 10kg/m², or as directed by the Engineer. Rollers shall comply with section 3.8.3.4 of this Specification.

The time between application of the bitumen at any location and the completion of spreading the aggregate over it at that location shall ensure that the bitumen is still within the specified temperature range and shall not exceed 3 minutes. The aggregate shall be rolled into the bitumen immediately using a rubber tyred roller for at least 4 passes and the road shall not be opened to traffic if this will cause any damage to the works.

3.11.4 Measurement

Surface dressing work shall be measured under this item by the number of square metres of acceptable work completed.

3.11.5 Payment

The quantity measured as provided above shall be paid for at the contract unit price per unit of measurement as shown in the Bill of Quantities, or on the drawings. The prices and payments shall be full compensation for cleaning, application of bitumen, compaction, furnishing the materials, testing, site trials and for all labour, tools, equipment and incidentals necessary to complete this item.

Pay item shall be:

3/11/1 Primer Seal

Square Metre

3.12 BITUMINOUS SURFACE TREATMENT (PLANT METHOD)

3.12.1 Description

Bituminous Surface Treatment shall consist of one or more applications of bituminous material and cover aggregate to a primed non-bituminous surface, or to a previously constructed bituminous surface, in accordance with these Specifications and to the area shown on the Drawings and as directed by the Engineer.

3.12.2 Materials

3.12.2.1 Bituminous Materials

Bituminous material shall be either RC 800 or RC 3000 cut back bitumen, rapid setting emulsion or, with the agreement of the Engineer 80/100 penetration grade bitumen conforming to the requirements of Section 3.7.2.1 of these Specifications. The bituminous material shall be approved by the Engineer.

3.12.2.2 Bitumen Additive

An Adhesion and Anti-stripping Agent shall be added to the bituminous material where so specified or when the Engineer so directs or approves. The additive shall be of a type approved by the Engineer and the required percentage of additive shall be thoroughly mixed with the bituminous material in accordance with the manufacturer's instructions, or as directed by the Engineer, for such time as is necessary to produce a homogeneous mixture.

3.12.2.3 Aggregates

Aggregates shall consist of clean, hard, dry, sound, crushed stone or crushed gravel of uniform quality, free from dust, clay, dirt and other deleterious matter and from excess of flat or laminated pieces. When crushed gravel is used, not less than 90% by weight of the particles retained on a 5 mm sieve shall have at least two fractured faces.

Aggregate shall be of such a nature that when thoroughly coated with the bituminous material proposed for the work, the coating will not be removed upon contact with water.

The aggregate when tested in accordance with STP 7.7.1 and 7.7.2 shall have an Aggregate Crushing Value less than 25 and a ten per cent fines value greater than 175 kN. The flakiness index as determined in accordance with STP 7.3.1 shall not exceed 25%.

Test results should be submitted to the Engineer for approval. The Engineer may require that other tests shall be carried out to determine its acceptability for surface treatment.

The grading of the aggregates shall fall within the limits specified in Table 3.12-1 for the appropriate specified nominal size.

Table 3.12-1

Grading Requirements for Cover Aggregate for Bituminous Surface Treatment			
Nominal Sieve Size	Aggregate Nominal Size		
	20 mm	14 mm	10 mm
	Percentage by weight passing square mesh sieves		
19	100	100	100
13.2	0 - 45	85 - 100	100
9.5	0 - 7	0 - 45	85 - 100
6.3	0 - 2	0 - 7	0 - 45
2.36	-	0 - 2	0 - 7
0.075	0 - 1	0 - 1.5	0 - 2

Notes on Table 3.12-1

- 1) For Single Surface Treatment either 20, 14 or 10 mm nominal size may be specified.
- 2) For Double Surface Treatment the first course may be either 20 mm or 14 mm followed by a second course of 10 mm nominal size.

Aggregate shall not contain sufficient moisture to cause uneven distribution of the pre-coating material and shall not be used in the work until the moisture has evaporated and the pre-coating material has adhered effectively to the aggregate.

3.12.2.4 Pre-Coated Aggregate

Aggregates shall be pre-coated with approved pre-coating material to improve the adhesion to the bitumen. Pre-coating material shall be thinly and evenly applied by means of a fine pressure spray to a moving stream of aggregate in an approved mixing plant so that all particles are fully coated but do not contain excess material. The coating shall be such that no material will drip from a particle of aggregate suspended between the fingers.

Pre-coating of aggregate shall not be carried out when rain is imminent unless the aggregate is adequately covered or unless the mixing of an adhesion agent in the pre-coating material has been authorised by the Engineer.

3.12.2.5 Stockpiling of Aggregates

Stockpiling of aggregates will be permitted only in designated areas approved by the Engineer. A separate stockpile shall be made for each nominal size of aggregate at each location.

In areas subject to dusty conditions, pre-coated aggregate shall not be stockpiled for any period longer than is necessary for moisture to dry out. When there is a visible coating of dust on the particles, the Engineer may direct that portion of the stockpiles be pre-coated again.

The site of the stockpile shall be cleared of all vegetation and debris, graded and drained, and, where the Engineer deems it necessary, the area shall be surfaced with a 100 mm layer of approved stone or with brick flat soling. In any case, the bottom 50 mm layer of aggregate or any contaminated aggregate shall not be used in the work.

Unless otherwise approved by the Engineer, each stockpile shall be built at least 2 metres high. The Contractor shall supply any planking or other material required in connection with movement of vehicles over and about the stockpiles.

3.12.3 Construction Methods

3.12.3.1 Equipment

Equipment described in this Section will be used for bituminous surface treatments unless the Engineer approves alternative construction methods proposed by the Contractor. Alternative construction methods would be particularly applicable to small areas and to the surfacing of footpaths and hard shoulders.

The Contractor shall supply all the plant and equipment necessary for carrying out the work in accordance with these Specifications and shall supply details of the make, model, capacity, weight and such other details of the plant and equipment as may be required by the Engineer.

For seal coats without cover aggregate, the equipment shall include a power brush, a self-powered bituminous material pressure distributor and, when necessary, equipment for heating bituminous material.

For seal coats with aggregate, and surface treatments, the equipment shall include a power brush, a drag brush, a bituminous material pressure distributor, a self-propelled pneumatic tyred roller, aggregate spreading equipment, an adequate number of trucks and, when necessary, equipment for heating bituminous material. A steel wheeled roller may be used only when so authorised by the Engineer.

In addition, when coated aggregates, bitumen additive or rubberised bituminous materials are specified, approved mixing plant shall be provided for the particular application.

Plant and equipment shall comply with the following requirements:

- a) The Bituminous Material Distributor shall conform to the requirements of Section 3.9.3.2
- b) The Power Brush shall be a rotary brush, towed or self-propelled, designed for sweeping road surfaces.
- c) The Drag Brush shall be capable of distributing unevenly spread aggregate without disturbing the particles freshly bedded in the binder.
- d) The Pneumatic Tyred Roller shall conform to the requirements of Section 3.8.3.4(G) (2).

- e) The Steel Wheeled Roller, where this type is permitted, shall have a load per 10 mm width of roll between 25 and 45 kg.
- f) The Aggregate Spreader shall be approved mechanical equipment capable of spreading a uniform layer of cover aggregate of the specified size.
- g) Motor Trucks shall be suitable in number and performance for the application of aggregate in accordance with Section 3.12.3.5.
- h) Heating Equipment shall be capable of producing uniform heating to the required temperature without damage to the bituminous material. An approved instrument for temperature measurement with an accuracy of 3% shall be provided. Means shall be provided to drain completely the heating tank or tanks. Suitable fire-fighting equipment and material shall be conveniently available to the heating equipment at all times when heating is in progress.

3.12.3.2 Weather Limitations and Control of Work

No spraying shall be carried out on a wet pavement, while rain appears imminent or during high winds. The Engineer may order work to cease temporarily on account of adverse weather. The Engineer may also order work to cease if the condition of materials is unsatisfactory, or conditions exist which he considers may affect the work adversely, for example the equipment or pavement is in unsatisfactory condition. The work will not be allowed to restart until the contractor has taken the necessary corrective action.

3.12.3.3 Cleaning and Preparation of Surface

No application of bituminous material shall be undertaken until the pavement has been cleaned to the satisfaction of the Engineer. Loose dirt and other objectionable material shall be removed from the surface by means of the power brush. If this does not provide a uniformly clean surface, additional sweeping shall be done by hand, using stiff bass or similar brushes. Sweeping shall extend at least 200 mm beyond each edge of the area to be sprayed.

Adherent patches of objectionable material shall be removed from the surface by steel scraper or other approved method, and where the Engineer so directs, the scraped area shall be washed down with water and hand brushes.

Where a prime coat has been applied to the surface, any area in which the prime coat has been insufficiently applied or is defective in any way shall be re-primed as directed by the Engineer. A period of at least 48 hours or such longer period as may be necessary for the primer to become completely dry shall elapse before any further bituminous material is applied.

Before application of the bituminous material, any necessary preliminary patching of the surface of the road shall have been completed to the satisfaction of the Engineer.

3.12.3.4 Application of Bituminous Material

The uniform application of bituminous material at the rate specified or ordered, reference is made to Table 3.12-2, shall be made by means of the distributor. For small areas, the Engineer may approve the application by means of hand spray equipment attached to the distributor.

For the particular bituminous material being used the application temperature shall be within the range included in Table 3.8-3. When an adhesion agent has been added to the bituminous material, the whole of the material in the distributor shall be circulated for at least fifteen minutes, or such greater time as may be necessary, to achieve a homogeneous mixture at uniform temperature.

Quantities of bituminous materials in excess of requirements shall not be heated, nor shall such materials be held within the range of the application temperatures for periods in excess of ten hours. Any bituminous material which has been heated for an excessive period of time, or which has been overheated, shall be rejected.

The area to be sprayed with bituminous material at any time shall be limited to that which can be covered with aggregate at the specified rate within 15 minutes of the time of spraying in the case of liquid asphalts, or such smaller duration of time as the Engineer shall direct.

When so directed, the bituminous material shall be applied in lanes of approximately one-half or less of the width of the completed surface and when so applied, there shall be a slight overlap of bituminous material along the adjoining edges of lanes. In the case of multiple surface treatments, succeeding courses shall have the bitumen joint offset by approximately 200 mm from the joint of the preceding application.

Table 3.12-2 Approximate Quantities of Materials for Surface Treatment per Square Meter

Approximate Quantities of Materials for Surface Treatment per Square Meter		
Nominal Size of Aggregate (mm)	Rate of Application	
	Kg of Aggregate	Liters Bituminous Material
20	20 – 32	1.2 - 2.2
14	12 – 20	0.8 - 1.5
10	8 – 15	0.7 - 1.2

Notes on Table 3.12-2

1. The quantities shown above are a guide only and will vary considerably according to the type and condition of the surface, the grading, type, shape and absorbency of the aggregate, the weather conditions and the traffic.
2. The bituminous material may be bitumen, cut back bitumen or bitumen emulsion as specified elsewhere in the Contract Documents. For seal coats, the Engineer may direct that emulsions shall be diluted with clean water in order to control the rate of application. This shall be done at the Contractor's expense.
3. In the case of multiple surface treatments a considerable variation of the quantities shown above for bituminous materials may be found necessary or desirable. The first application of bitumen may be reduced and subsequent applications increased if this provides a better result.
4. The rates may be specified by the Engineer, but normally the Contractor will be required to carry out trials at the Contractor's expense. These should use materials in the range indicated in Table 3.12-2, and be on areas other than the Project road surface, in order to allow the necessary rates to be established. These rates should be agreed with the Engineer and utilised for the bituminous surface treatment on the Project road surface and these will produce the actual quantities for the works.

A minimum of two tests for each day's work shall be carried out by the Contractor, under the supervision of the Engineer, in order to verify that the actual rate of application of aggregates and bituminous material complies with the specified rate or those established by the trials and agreed by the Engineer. If the measured application rates vary within $\pm 10\%$ of the established rates, the work will be accepted.

Should the measured application rates for bituminous surface treatment be greater than $\pm 10\%$ of the rates ordered, the Engineer shall decide if the concerned work shall be condemned. Such condemned defective bituminous surface treatment shall be completely removed, and the work will be carried out again with all abortive and additional work being at the Contractor's expense.

When surface treatment is being applied to the shoulders of the carriageway, the Contractor shall take suitable precautions to prevent contamination of the finished carriageway surface with bituminous material. However, the bituminous material shall slightly overlap the adjoining bituminous concrete surface to prevent the ingress of water along the joint.

During all applications, iron work in the road shall be covered with heavy oil or grease and the surfaces of adjacent structures and trees shall be protected in such manner as to prevent their being splashed or damaged.

Suitable paper or metal sheets shall be spread on the ground for a sufficient distance back from the ends of each application so that flow through the nozzles may be

started and stopped on the paper or metal sheets and so that all nozzles will operate properly over the entire length being treated. The distributor shall commence moving at a sufficient distance in advance of the start of the application to ensure that the road speed for the correct application rate is attained at the commencement of spraying and this speed shall be maintained until past the finishing point of the application.

After each application, the quantity of material sprayed shall be checked against the area covered, and any necessary adjustments shall be made to ensure that the specified or ordered rate of application is maintained in subsequent runs.

Spraying shall cease immediately if any defect develops in the spraying equipment and it shall not re-commence until the fault has been rectified.

3.12.3.5 Application of Cover Aggregate

Before the bituminous material is applied, sufficient cover aggregate shall be in trucks at the site of the work to fully cover the area to be sprayed. The application of the aggregate shall proceed immediately after spraying of the bituminous material and shall be completed within 15 minutes of the completion of spraying or such smaller period of time, as the Engineer shall direct.

The aggregate shall be spread uniformly over the bituminous material by means of the approved aggregate spreader at either the rate specified or as determined by trials. Any bare or insufficiently covered areas shall be re-run by the mechanical spreader or covered by hand as necessary to give uniform and complete coverage. Any aggregate spread in excess of the rate specified or ordered shall be scattered and evenly distributed on the road or otherwise removed and stockpiled as directed by the Engineer.

3.12.3.6 Rolling and Brushing

Immediately after spreading to the satisfaction of the Engineer, the aggregate shall be rolled with one or more pneumatic tyred rollers or, if permitted by the Engineer, by approved steel wheeled rollers, until the aggregate is firmly embedded in the bituminous material. Where required to ensure an even distribution of aggregate, the surface shall be drag brushed after the initial rolling except that if the drag brush has any tendency to dislodge aggregate particles bedded in the binder, the Engineer may direct that drag brushing be deferred or eliminated, and that light hand brushing be substituted. Rolling shall be continued, as directed by the Engineer, for as long as is necessary to ensure thorough incorporation of the aggregate into the binder.

Immediately after the binder has hardened to the stage at which, in the opinion of the Engineer, no more aggregate can be pressed into it by rolling, any remaining loose particles shall be removed from the pavement and shoulders.

If, after spreading, the aggregate is found to contain moisture and weather conditions are suitable for drying, the Engineer may allow the rolling of the aggregate to be deferred for a short time to permit the moisture to evaporate providing that

satisfactory adhesion of the binder to the aggregate is obtained. If the Engineer considers that the adhesion of the binder to the aggregate is unsatisfactory, he shall reject the work and direct that no further work be carried out until the conditions improve.

3.12.3.7 Control of Traffic

The Contractor shall comply with Section 1.1 of this Specification. In addition the Contractor shall take all necessary precautions to protect the work from damage until such time as the seal coat or surface treatment has developed sufficient strength to carry normal traffic without disturbance of the aggregate. Where it is necessary to allow early use of the new work to facilitate the movement of traffic, vehicles may be allowed to run on the work after rolling is completed provided that vehicles are controlled to such slow speeds that no displacement of aggregate occurs.

No traffic shall be permitted to pass the working area during the application of bituminous material nor shall traffic be permitted to encroach upon the edge of bituminous material until such time as it is covered with aggregate.

3.12.4 Measurement

The Bituminous Surface Treatment works of the type stated in the Bill of Quantities shall be measured in square metres of the completed and accepted works as detailed on the drawings or as directed by the Engineer.

3.12.5 Payment

The quantities, measured as provided above, shall be paid for at the Contract unit price per unit of measurement, shown in the Bill of Quantities. The prices and payment shall be full compensation for trial mixes, furnishing, and placing all materials, including all labour, equipment, tools and incidentals necessary to complete the Works.

Where defective work is corrected, or additives used which have not been specified or ordered by the Engineer, no payments will be made in respect of extra work or materials used in excess of the quantities specified or ordered. The use of Adhesive and anti-stripping Agent/ bitumen Additive will not be paid for separately, and any costs involved should be included in this item. Pre-coating of chippings shall be carried out without any additional payment.

Pay items shall be:

3/12/1	Single Bituminous Surface Treatment	Square Metres
3/12/2	(a)Double Bituminous Surface Treatment- 20mm nominal size aggregate followed by 10mm (Machine Method)	Square Meters
3/12/2	(b)Double Bituminous Surface Treatment- 14mm nominal size aggregate followed by 10mm (Machine Method)	Square Meters

3.13 DENSE BITUMINOUS SURFACING (PENETRATION GRADE BITUMEN)

3.13.1 Description

3.13.1.1 General

This work shall consist of a surfacing of dense graded bituminous material, constructed on a prepared aggregate base in accordance with these Specifications, to the lines, levels, grades, dimensions and cross sections shown on the Drawings, or as required by the Engineer.

All the provisions of Section 3.8, “General Requirements for Bituminous Surfacing” shall form a part of this Section of the Specifications unless otherwise stipulated herein.

The surfacing shall consist of one or two layers of the thickness shown on the Drawings. If the surfacing is of two layers the top layer shall be denoted as the wearing course and the lower layer as the base course.

3.13.1.2 General Composition of the Mixture

The mixture shall consist of mineral aggregate added with 2% hydrated lime powder or Portland Cement filler complying with section 3.8.2.3 of these Specifications, if needed, coated with bitumen with the materials complying with Section 3.8.2 of these Specifications and with Table 3.13-1. No natural sand shall be allowed in the Bituminous Mix.

When the total thickness of bituminous surfacing exceeds 90mm, the material may be laid in two courses if directed by the Engineer.

The base course shall be within the limits set by mix classification 1 in Table 3.13-1 and the wearing course by mix classification 2 in the same table. The mix classification shall be as specified in the contract; in case the mix classification is not specified in the contract, it shall be the one instructed by the Engineer.

When the total thickness of bituminous concrete is 50 mm or less the material shall be laid in a single course within the limits set by mix classification 2 in Table 3.13-1.

Table 3.13-1 Mix Classification

Course	1		2
	Dense Bituminous Surface-Base Course		Dense Bituminous Surface-Wearing Course
Thickness (mm)	60 -90	50 - 60	40 - 50
Sieve Size (mm)	Total % by weight passing (including filler)		
37.5	100	100	100
26.5	75 – 90	100	100
19	65 – 85	85 – 97	100
13.2	55 -75	70 – 82	75 – 87
9.5	45 -65	61 – 73	63 – 75
4.75	30 -50	43 - 55	47 – 57
2.36	21 -38	29 – 38	33 – 42
1.18	14 -30	20 -28	23 – 32
0.60	10 -23	13 – 21	15 – 24
0.30	6 -17	8 -16	10 – 18
0.15	4 -12	5 – 12	6 – 13
0.075	3 -8	3 – 8	3 -4 - 8

The ratio of total material passing the 0.075 mm sieve to effective bitumen content shall be within the range 0.6 to 1.2. The minimum bitumen content (by total weight of mixture) shall be 4.0% and 4.8% for Dense Bituminous Base Course and Dense Bituminous Wearing Course respectively.

Coating thickness or asphalt film thickness shall be minimum 8 micron. Film thickness shall be determined using following equation

$$F = \frac{P_{be}}{100 - P_b} * \frac{1}{A} * \frac{1}{S} * 10^6$$

Where, F= Film Thickness in micron. P_{be}=effective asphalt content (%), P_{be}=Total asphalt content (%), S=density of asphalt in kg/m³, A=Surface Area (m²/kg) will be determined from MS 2-2014, Chapter 8, Hveem Method of Mix Design, Page 94 or IRC: SP:135- 2022.

In addition to meeting the requirements of the grading and quality conformity of the individual ingredients, the mixture shall meet the following requirements set out in Table 3.13-2.

Table 3.13-2: Requirements for Dense Bituminous Surfacing

Marshal Properties	Marshall Method (STP 10.9)	Modified Marshall Method (ASTM D5581)	Test Method
Compaction	75 blows on each face	112 blows on each face	
Minimum Stability at 60°C (kg)	~~1300~~ 1000	~~2925~~ 2000	
Marshall Flow (mm)	2.0 – 4.0	3.0 – 6.0	
Air Void (%)	3 - 5		
VFA (%)	65 – 80 (base course) 70 – 80 (wearing course)		
VMA (%)	Table 3.13-3		

Where maximum size of the aggregate is more than 25.0 mm, the modified Marshall method with 150 mm diameter specimen described in ASTM D 5581 shall be used.

Table 3.13-3: VMA criteria for different aggregate size

Nominal Maximum Aggregate Size, mm	Minimum Design VMA, volume %
37.5	11
26.5	12
19.0	13
13.2	14
9.5	15
4.75	16

The bituminous mix for base/wearing course, when subjected to Water Sensitivity Test as per AASHTO-T283, the loss in strength shall not exceed 20% of the original mix. This test shall be carried out at the time of mix design and subsequently as and when required by the Engineer.

If specified in the Particular Specification AASHTO T324-19 and/or AASHTO T 322 – 07 tests shall be done. AASHTO T324-19 Test shall be conducted for rutting simulation for traffic and waterlogging case. If the Stripping Inflection Point occurs at a low number load cycles e.g. less than 10000, the bituminous mix shall be considered susceptible to moisture damage. Recommended maximum rut depth at 10000 and 20000 load cycles shall be of 4 mm and 10 mm respectively. To determine the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Indirect Tensile Test as per AASHTO T 322 – 07 shall be used.

3.13.2 Materials

3.13.2.1 General

The materials shall conform to Section 3.8.2 of these Specifications with the additional requirements noted below.

3.13.2.2 Bituminous Materials

These materials shall conform to the requirements of Section 3.7. The bituminous material shall be of 40/50 or 60/70 penetration grade bitumen as specified in particular specification.

3.13.2.3 Bitumen Additive

An adhesion and anti-stripping agent shall be added to the bituminous material where so specified or when the Engineer so directs or approves. The additive shall be of a type approved by the Engineer and the required percentage of additive shall be thoroughly mixed with the bituminous material in accordance with the manufacturer's instructions, or as directed by the Engineer, for such time as is necessary to produce a homogeneous mixture.

3.13.2.4 Coarse Mineral Aggregates

The provisions of Section 3.8.2.1 shall apply.

3.13.2.5 Fine Mineral Aggregate

The provisions of Section 3.8.2.2 shall apply.

3.13.2.6 Mineral Filler

The provisions of Section 3.8.2.3 shall apply.

3.13.2.7 Mixture

Regular checks shall be made on the composition of the mixed material. The Contractor shall take samples at either the batching plant or at the job site, as directed by the Engineer, and shall arrange for Marshall/ Modified Marshall Specimens to be prepared (STP 10.9/ ASTM D5581) and tested for stability and flow. Samples shall also be analysed to determine the mix composition, by extraction of the bitumen in accordance with STP 10.4 and aggregate grading.

A minimum of three Marshall Specimens shall be prepared for each day or part of a day that the batching plant is operated and dense bituminous surfacing is laid and a minimum of two bitumen extractions and aggregate gradings shall also be carried out. If the contractor can demonstrate good quality control of the plant, through consistent and acceptable test results being obtained, then less frequent testing may be permitted, at the discretion of the Engineer.

3.13.3 Construction Methods

3.13.3.1 General

Construction methods shall conform to the requirements of Section 3.8.3 of these Specifications subject to the following modifications.

3.13.3.2 Preparation of Bituminous Material

Bitumen shall be heated as per Table 3.8-3. The Contractor shall submit a single definite temperature for the Engineer's approval.

3.13.3.3 Preparation of Mineral Aggregate

The mineral aggregates shall be dried and heated as per Table 3.8-3, so that the surfaces of aggregates are clean and free of carbon and unburned fuel oil. The Contractor shall submit a single definite temperature for the Engineer's approval.

The mineral aggregates shall be dried so that no steaming, bubbling, foaming, brown colouring or slumping of the newly produced mixture can be seen when the mix is loaded on the trucks or placed on the road.

If any traces of insufficient drying are observed, the Contractor shall take such of the following steps as are necessary to provide properly dried aggregates:

- 1) Maintain the level of the material in the hot bins above the two-thirds level.
- 2) Reduce the rate of cold feed.
- 3) Lower the slope of the drier as much as practicable.
- 4) Adjust exhaust fan, burner and air intake so as to provide longer flame penetration into the drier.

If all the preceding steps have been carried out and the mineral aggregate is still not dried to the satisfaction of the Engineer, double drying will be required for all or part of the aggregate.

3.13.3.4 Preparation of Mixture

The mixture shall when emptied from the mixer be at a temperature as per Table 3.8-3. A single definite temperature shall be submitted for the Engineer's approval in accordance with Section 3.8.1.3.

3.13.3.5 Spreading and Compaction

Unless the bituminous premix is laid directly onto a clean prime coat, a tack coat shall be applied in accordance with Section 3.10, to the underlying surface prior to spreading the base and wearing courses.

Non-inclusion of Tack Coat as a separate BoQ item or insufficient quantity of Tack Coat in the Bill of Quantities (BoQ) shall not relieve the contractor from the obligation of applying Tack Coat to the underlying surfaces.

For regulation courses the thickness of a compacted layer shall not be less than twice the maximum stone size.

To avoid traffic disruption, the spreading and compaction is often carried out over half the road width only. Rollers shall not be allowed to stand on newly laid material that may be deformed thereby. Sections of newly laid base course shall be kept clean prior to laying the surface course and no traffic except in connection with laying the surface course shall be permitted on the prepared base course.

The mixture shall be compacted as soon after being placed as the material will support the roller without undue displacement or cracking and sufficient compaction plant should be deployed so that the required degree of compaction is achieved before the material has cooled to a specific temperature as per Table 3.8-3. Smoothing rolling may continue longer, if necessary, as long as the temperature of the mat is as per Table 3.8-3. The average field density of any bed of base course and wearing course shall be between 94 – 96 percent of theoretical maximum density of the mix (AASHTO T 209 12 – 2016), from the sample taken behind the paver. No individual density test result shall fall below 93% of the theoretical maximum density of the mix.

3.13.3.6 (A) Joints (transverse joint)

The work shall be organised so that transverse joints are kept to a minimum and, where practical, only occur at specified positions (i.e. bridges etc.). All transverse joints are to be cut back to well compacted full depth material to produce a straight vertical joint which is to be painted with bitumen before laying of new material.

B) Longitudinal Joint Construction techniques in HMA in Pavements

All longitudinal joints shall be offset at least 300 mm from parallel joints in the layer beneath or as directed and in a layout approved by the Engineer.

3.13.3.7 Protection of the Pavement

Sections of the newly finished work shall be protected from traffic of any kind until the mixture has cooled to approximately ambient air temperature. Traffic shall not normally be permitted on the newly laid surface less than 12 hours after completion of the pavement, except with the approval of the Engineer.

3.13.3.8 Pavement Samples

The Contractor shall, after final rolling and before opening the surface to traffic, cut samples from the finished work for testing. Samples for the full depth of the course shall be cores with diameters of 100 or 150 mm depending on size of mould used in preparation of Marshall Mix Design, or directed, and cut using an approved coring machine, from the locations directed by the Engineer.

At least two samples for density measurement shall be taken for each day or part of a day that the plant operates or if the output exceeds 100 tonnes per day, then at the rate of two per 100 tonnes or part thereof.

Samples for analysis and other tests shall be taken from the surfacing when the Engineer so directs. Where samples have been taken from the surface course, fresh material shall be placed, thoroughly compacted and finished to the satisfaction of the Engineer.

3.13.3.9 Surfacing Texture

The surface finish of the base course shall be close and tight, while the surface finish of the wearing course shall be equally well bound, though where the mix permits the surface shall be textured so as to enhance surface friction, but free from dragging cracks or other surface blemishes. Back casting shall not normally be permitted but when dragging occurs under the screed of the spreader, fine bituminous material may be cast over the surface to fill the dragging cracks, providing that this is done before the initial rolling and providing that rolling is carried out at specified temperature. Should dragging occur frequently the reason is to be determined and rectified.

3.13.4 Measurement

The quantities of dense bituminous pavement measured for payment shall be the number of cubic metres of accepted and completed surfacing, of the widths and thickness shown on the Drawings. However, the Contractor should allow in his rates for additional material used for forming sloping edges, waste, over spill, joints, cut-backs etc. Should the widths and/or thickness of completed and accepted surfacing be less than indicated on the Drawings, the quantities measured for payment will be based on the actual widths and/or thickness. No adjustment in payment will be made where the pavement widths and thickness as laid and approved are greater than those specified.

The surface profiles of courses will be used in the measurement of course thickness, unless an alternative method, such as core thickness, is approved by the Engineer.

3.13.5 Payment

The quantities of dense bituminous surfacing measured as provided above shall be paid for at the Contract unit rates. The rates and payments shall be full compensation for furnishing and placing all materials including all labour, equipment, tools, trials, preparation of job-mix formulae, testing, making good test holes and all incidentals necessary to complete the work. Tack coat shall not be paid for separately except where specifically provided in the Contract Documents.

When Tack Coat is included as a separate BOQ item in the Contract Document, but the quantity is not sufficient to cover all the bituminous works under the BOQ, the cost of quantity of Tack Coat required in addition to the BOQ provision shall be considered

to be included within the rates of bituminous layer. The contractor is advised to make necessary adjustments accordingly in his rates of bituminous layers.

Pay items shall be:

3/13/1	Dense Bituminous Surfacing - Base Course (Pen grade bitumen)	Cubic Metre
3/13/2	Dense Bituminous Surfacing -Wearing Course (Pen grade bitumen)	Cubic Metre

3.14 DENSE BITUMINOUS SURFACING (POLYMER MODIFIED BITUMEN)

3.14.1 General Description

This specification covers the requirements for Dense Bituminous Surfacing (Base and Wearing course) using Polymer Modified Bitumen (PMB) for high-performance pavement construction, rehabilitation, and maintenance works requiring superior resistance to rutting, thermal cracking, and fatigue damage

All the provisions of Section 3.8, “General Requirements for Bituminous Surfacing” shall form a part of this Section of the Specifications unless otherwise stipulated herein.

The surfacing shall consist of one, two or three layers of the thickness shown on the Drawings. If the surfacing is of two layers the top layer shall be denoted as the wearing course and the lower layer as the base course. If the surfacing is of three layers, the top layer shall be denoted as the wearing course, the middle layer as bituminous binder coarse and the lower layer as the bituminous base course.

3.14.1.1 General Composition of the Mixture

The mixture shall conform to the requirements of section 3.13.1.2 with the following modifications.

Table 3.14-1: Requirements for Dense Bituminous Surfacing with Polymer Modified Bitumen

Marshal Properties	Marshall Method (STP 10.9)	Modified Marshall Method (ASTM D5581)	Test Method
Compaction	75 blows on each face	112 blows on each face	
Minimum Stability at 60°C (kg)	1200	2200	AASHTO T245
Marshal Flow (mm)	Min. 2	Min. 2	AASHTO T245

3.14.2 Materials

3.14.2.1 General

The materials shall conform to Section 3.8.2 of these Specifications with the additional requirements noted below.

3.14.2.2 Bituminous Materials

The base bitumen used for polymer modification shall be virgin asphalt binder meeting the requirements for unmodified Performance Grade (PG) binder prior to modification. Minimum PG High Temperature Grade 70°C (based on climate analysis and heat wave considerations). The bitumen PG 70, PG 76, and PG 82

shall be used, as specified in the Particular Specifications for standard hot, very hot, and extreme hot climate zone, respectively. Standard Low Temperature Grade -10°C shall be used. The properties of the original bitumen and aged bitumen shall comply with Table 3.14-2 and Table 3.14-3, respectively.

Table 3.14-2: Original Binder Properties

Property	Test Method	Requirement
Flash Point	ASTM D92	Min. 230°C
Viscosity @ 135°C	ASTM D4402	Max. 3.0Pa·s
Dynamic Shear $G^*/\sin \delta$ @ test temp	ASTM D7175	Min. 1.00kPa
Separation Index (Difference in Softening Point)	ASTM D7173	Max. 2.2°C
Elastic Recovery @ 25°C	AASHTO T301	Min. 90%
Polymer Content (FTIR)	AASHTO T302	3.0% - 6.0% SBS

Table 3.14-3(a): Aged Binder Properties (RTFO Residue)

Property	Test Method	Requirement
Mass Loss	ASTM D2872	Max. 1.0%
Dynamic Shear $G^*/\sin \delta$ @ test temp	ASTM D7175	Min. 2.20kPa

Table 3.14-3(b): Long-Term Aged Binder Properties (PAV Residue)

Property	Test Method	Requirement
Dynamic Shear $G^* \sin \delta$ @ test temp	ASTM D7175	Max. 5,000kPa
Flexural Creep Stiffness @ test temp	ASTM D6648	Max. 300MPa
Direct Tension Failure Strain	ASTM D6723	Min. 1.0%

3.14.2.3 Polymer Modifier

Only Elastomeric Polymers shall be used, specifically Styrene-Butadiene-Styrene (SBS) block copolymers and Linear or radial configuration SBS polymers. The polymer content shall be in the range of 3.0% to 7%. The Styrene content shall be 28% to 32%. Whereas, the Molecular weight 80,000 to 150,000 and the Polydispersity index shall be equal to or more than 3.0.

3.14.2.4 Additives (if required)

An additive or Cross-linking agent (sulfur) 0.05% to 0.15% by weight of bitumen shall be used. The manufacturer may recommend using an Antioxidant. Processing aids of maximum 0.5% by weight of bitumen could be used in required cases.

3.14.2.5 Performance Requirements of the binder

PMB shall comply with AASHTO M332 (Performance-Graded Asphalt Binder Using Multiple Stress Creep and Recovery (MSCR) Test) which is equivalent to ASTM D8239-21.

Table 3.14.-4: MSCR (Multiple Stress Creep and Recovery) Requirements

Traffic Level	ESAL Range	MSCR Grade	Jnr @3.2kPa (kPa ⁻¹)
Heavy (H)	3-10 million	H	≤2.0
Very Heavy (V)	10-30 million	V	≤1.0
Extreme (E)	30-80 million	E	≤0.5
Ultra Heavy	>80million	Custom	≤0.2
Minimum 30% recovery at 3.2 kPa stress level			

3.14.2.6 Physical property requirements of the PMB

a) Storage and Handling Requirements

Vertical storage position is required. Insulated storage tanks with temperature monitoring shall be equipped through calibrated temperature gauges at tank and outlet points. Temperature recording devices with automatic controls are preferable. The tank shall be facilitated with a continuous agitation or circulation system. The maximum storage temperatures shall be 180°C. Maximum continuous storage time shall be 5 days at 180°C. The maximum heating rate shall be 15°C per hour (unless mechanically agitated), and avoid overheating above 180°C for extended periods

To prevent contamination, dedicated storage tanks for PMB (no mixing with conventional bitumen) shall be arranged by the Contractor. Proper flushing procedures shall be followed for changing products. The petroleum product contamination prevention protocols shall be followed strictly.

b) Storage stability requirements:

Storage stability is critical for PMB quality and shall be evaluated using ASTM D7173. The maximum difference in softening point between top and bottom sections shall be 2.2°C. However, the differential 2.2°C - 3.0°C would be acceptable with proper handling. In case

of temperature difference more than 3.0°C of the stored product shall be unacceptable and it shall require formulation adjustment. The test procedure shall be followed as below:

Storage temperature: 180°C ± 5°C

Storage duration: 48 ± 1 hours

Sample size: 50 ± 0.5g in aluminum tubes

b) Polymer Analysis Requirements

PMB shall be analyzed with Microscopy Analysis (EN 13632:2010) to ensure uniform polymer dispersion without phase separation. Small to medium-sized SBS grains are preferable to formulation of homogeneous polymer distribution.

FTIR Analysis (AASHTO T302) shall be used for verification of SBS polymer and quantitative analysis. The peak analysis at 965 cm⁻¹ shall be done for SBS identification.

c) Manufacturing requirements

PMB shall be manufactured using high-shear mixing equipment. The mixing temperature shall be within 160°C to 190°C. Mixing time shall be a minimum 2 hours for complete polymer dispersion. The polymer dispersion shall be checked every 2 hours and the PMB viscosity checked in every 4 hours. The Storage stability testing and batch certificates with results shall be provided in each delivery. For immediate use PMB may be produced at site by installing desired capacity as mentioned in the Contract or decided by the Engineer.

3.14.3 Quality control and testing

The minimum testing frequency shall be 1 test per 100 tons of PMB mixture. The acceptance criteria shall be:

Individual test results: Within ±5% of specification limits

Average of 3 consecutive tests: Within ±3% of specification limits

No single test result shall exceed specification limits

3.14.3.1 Coarse Mineral Aggregates

The provisions of Section 3.8.2.1 shall apply.

3.14.3.2 Fine Mineral Aggregate

The provisions of Section 3.8.2.2 shall apply.

3.14.3.3 Mineral Filler

The provisions of Section 3.8.2.3 shall apply.

3.14.3.4 Mixture

The provisions of Section 3.13.2.7 shall apply.

3.14.4 Construction Methods

Construction methods shall conform to the requirements of Section 3.13.3 of these Specifications subject to the following modifications. The maximum hauling time shall be 04 hours to maintain the mixture temperature. Handwork to be minimized due to high viscosity mix. The maximum cooling time before compaction completion shall be 2 hours. The temperature control shall be followed strictly according to Table 3.8-3.

Initial breakdown roller will be done by steel wheel roller of 16 to 19 ton capacity. Other Steel wheeled tandem rollers shall weigh not less than 10 metric tons. Pneumatic type rollers shall be of an approved type having not less than seven wheels with smooth tread compactor types of equal size and each roller shall be so equipped that its total weight is adjustable by ballasting allowing the load per wheel to be varied from 2,000 to 3,000 kilograms.

3.14.5 Measurement

The quantities of dense bituminous pavement measured for payment shall be the number of cubic meters of accepted and completed surfacing, of the widths and thickness shown on the Drawings. However, the Contractor should allow in his rates for additional material used for forming sloping edges, waste, over spill, joints, and cut-backs etc. Should the widths and/or thickness of completed and accepted surfacing be less than indicated on the Drawings, the quantities measured for payment will be based on the actual widths and/or thickness. No adjustment in payment will be made where the pavement widths and thickness as laid and approved are greater than those specified.

The surface profiles of courses will be used in the measurement of course thickness, unless an alternative method, such as core thickness, is approved by the Engineer.

3.14.6 Payment

The quantities of dense bituminous surfacing measured as provided above shall be paid for at the Contract unit rates. The rates and payments shall be full compensation for furnishing and placing all materials including all labour, equipment, tools, trials, preparation of job-mix formulae, testing, making good test holes and all incidentals necessary to complete the work. Tack coat shall not be paid for separately except where specifically provided in the Contract Documents.

When Tack Coat is included as a separate BoQ item in the Contract Document, but the quantity is not sufficient to cover all the bituminous works under the BoQ, the cost of quantity of Tack Coat required in addition to the BoQ provision shall be considered to be included within the rates of bituminous layer. The contractor is advised to make necessary adjustments accordingly in his rates of bituminous layers.

Pay items shall be:

3/14/1 Dense Bituminous Surfacing- Base Course (PMB)	Cubic Metre
3/14/2 Dense Bituminous Surfacing- Wearing Course (PMB)	Cubic Metre

3.15 BITUMINOUS CARPETTING (PLANT METHOD)

3.15.1 Description

3.15.1.1 General

This work shall consist of a surfacing of bituminous material, constructed on a prepared base in accordance with these Specifications, to the lines, levels, grades, dimensions and cross sections shown on the Drawings or as required by the Engineer. Bituminous Carpeting will be applicable for Maintenance and Emergency purpose and needs special permission from Proper Authority.

The provisions of Section 3.8, “General Requirements for Bituminous Surfacing” shall form a part of these Specifications except that the requirements for plant mixing and laying by paving machine may be relaxed for smaller works provided that the contractor proposes and demonstrates effective alternative methods to the full satisfaction of the Engineer. However, the requirement for plant mixing shall not be relaxed for bituminous works exceeding 01 km in total length. Such methods shall take account of the total quantity of material to be mixed and laid within the stipulated programme. Any alternative methods shall only be employed after receipt of written approval from the Engineer. Such approval may be withdrawn at any time if the work is found to be unsatisfactory.

Bituminous carpeting shall consist of one or two layers of binder course of the total thickness shown on the drawings or as directed by the Engineer.

3.15.1.2 General Composition of the Mixture

The mixture shall consist of mineral aggregate and filler if needed, coated with bitumen, with the materials complying with Section 3.8.2 of these Specifications.

When the total thickness of bituminous base (binder) course exceeds 50 mm, the material may be laid in two layers if so directed by the Engineer. The material shall conform to the mix classification 1 in Table 3.15-1.

The selected job-mixes shall conform to Table 3.15-1, unless with the specific approval of the Engineer.

Table 3.15-1 Gradation Requirements for bituminous carpeting

Mix classification Course Thickness (mm)	1 Base (Binder) 25	2 Base (Binder) 38 or 50
Sieve Size (mm)	Total % by weight passing	
26.1	100	100
19	100	75-100
13.2	75-100	60-80
9.5	60-80	-
4.75	40-60	40-60
2.36	20-35	20-38
0.6	10-20	6-18
0.075	2-8	2-8
Bitumen Content % by weight of total mixture.	5.5%± 0.3% (5.2% - 5.8%)	5.2%± 0.3% (4.9% - 5.5%)

3.15.2 Materials

3.15.2.1 General

The materials shall conform to Section 3.8.2 of these Specifications with the additional requirements noted below.

3.15.2.2 Bituminous Materials

These materials shall conform to the requirements of Section 3.7. The bituminous material shall be 60/70 penetration grade.

3.15.2.3 Coarse Mineral Aggregate

The provision of Section 3.8.2.1 shall apply.

3.15.2.4 Fine Mineral Aggregate and Mineral Filler

The provision of Sections 3.8.2.2 and 3.8.2.3 shall apply.

3.15.2.5 Mixture

The Contractor shall carry out regular checks at frequency to be determined by the Engineer on the composition of the mixed material and shall submit results to the Engineer within 3 days of sampling.

3.15.3 Construction Methods (Plant)

The construction method shall be followed as described in section 3.13.3 and as when required Manual method shall be followed with the approval of the Engineer applicable for short road sections/isolated location of road sections

3.15.4 Measurement

The quantity of bituminous carpeting measured for payment shall be the number of cubic metres accepted and completed surfacing to the width and thickness shown on the Drawings. Should the widths and/or thickness of the surfacing be less than indicated on the Drawings, the quantities measured for payment will be based on the actual widths and/or thickness.

The bituminous carpeting shall be measured as the net dimensions of the top surface of each course and the Contractor will make allowance in his rate for additional material used for forming sloping edges and over spill.

3.15.5 Payment

The quantities measured as provided above, shall be paid for at the Contract unit price rates. The prices and payments shall be full compensation for furnishing and placing all materials including all labour, equipment, tools, trials, preparation of job-mix formulas, testing, making good test holes, and incidentals necessary to complete the work. Tack coat shall not be paid for separately except where specifically provided for in the Contract Documents.

Pay items shall be:

3/15/1	Premix Bituminous Carpeting	Cubic Metre

3.16 PREMIX BITUMINOUS SEAL COAT (MANUAL METHOD)

3.16.1 Description

3.16.1.1 General

This work shall consist of a premix bituminous seal coat applied to newly laid bituminous carpeting, or a prepared and primed granular base course, or existing bituminous surface in accordance with these Specifications. The thickness of the premix bituminous seal coat shall be 7 mm, 12 mm or 15 mm as directed and shall be to the lines, levels, grades dimensions and cross sections shown on the Drawings or as required by the Engineer.

The provisions of Section 3.8, "General Requirements for Bitumen Bound Surfacing (Plant Method)" shall form a part of these Specifications except that the requirements for plant mixing and laying by paving machine may be relaxed for smaller works provided that the contractor proposes and demonstrates effective alternative methods to the full satisfaction of the Engineer. However the requirement for plant mixing shall not be relaxed for bituminous works exceeding 01 km in total length. Such methods shall take account of the total quantity of material to be mixed and laid within the stipulated programme. Any alternative methods shall only be employed after receipt of written approval from the Engineer. Such approval may be withdrawn at any time if the work is found to be unsatisfactory.

3.16.1.2 Composition of the Mixture

The mixture shall consist of aggregate and sand, coated with bitumen with the materials complying with Section 3.8.2 of these specifications. The Contractor shall meet the requirements of the job mix formula in section 3.8.1.3 and the tolerances in Section 3.8.1.4

The material shall conform to Table 3.16-1 below, unless otherwise directed by the Engineer in writing.

Table 3.16-1: Gradation requirements for premix bituminous seal coat

Mix Classification Course Compacted Thickness (mm)	Seal Coat 7 mm	Seal Coat 12 or 15 mm
Sieve Size (mm)	Total % by weight passing	
9.5	-	100
6.3	100	90-100
4.75	90-100	75-95
2.36	70-95	20-50
0.6	20-50	5-15
0.075	5-15	2-10

3.16.2 Materials

3.16.2.1 General

The materials shall conform to Section 3.8.2 of these specifications with the additional requirements noted below.

3.16.2.2 Bituminous Materials

These materials shall conform to the requirements of Section 3.7. The bituminous material be 60/70 or 80/100 penetration grade

3.16.2.3 Mineral Aggregate

Aggregates shall consist of 6.3mm or 10mm downgraded pea gravel free from any organic matter clay and any other objectionable matter.

Where required to achieve the specified grading the aggregate shall be mixed with natural sa Sand shall be doo plastic, clean and free from any deleterious substances. The minimum FM sand for the sealing premix shall be between 2.00 to 2.50 and that of sand to be spread over seal coat as blotting material shall be between 0.80 to 1.00.

The mix of the aggregates and sand combined shall comply with the grading given in Table 3.16-1

3.16.2.4 Mixture

The Contractor shall carry out regular checks at frequency to be determined by the Engineer o the composition of the mixed material and shall submit results to the Engineer within 3 days sampling.

3.16.3 Construction Methods

3.16.3.1 General

Construction methods shall conform to the general requirements of Section 3.8.3 of these Specifications subject to the following modifications. For smaller works, where the requirement for plant mixing has been relaxed by the Engineer, the relevant provisions contained in Section 3.8.3 shall be replaced by those under Sections 3.16.3.2, 3.16.3.3 and 3.16.3.4 of these Specifications.

Following approval of the mix formula the contractor shall undertake short trial sections of approximately 10 meter length, prior to commencing contract surfacing. These trials are to demonstrate that the contractor and the laying staff understand and can apply the specification correctly to produce the quality of work specified on a consistent basis. The trials will also be used to fine tune the mix design if required.

If the trial works are suitable, they may be accepted in the contract works. If the trial work has be rejected, they can be permitted to remain in the works until replacement near the end of the contract, so that unspecified work can be monitored and used to demonstrate to other contractors and supervision staff the defects that will manifest themselves if work is carried out using unspecified materials, workmanship or methodology.

Once the Contractor has demonstrated an acceptable procedure, he shall submit in writing his full method statement for the Engineer's approval. No surfacing works will be permitted until the Engineer's approval has been granted, in writing, and once approved the method shall not be varied in any way without reference to, and approval of the Engineer.

The Contractor shall furnish a thermometer at each mixing unit to ensure that temperature of bitumen, mineral aggregates and bituminous mixture shall be within the specified ranges stipulated in 3.16.3.2 through 3.16.3.5.

3.16.3.2 Preparation of Bituminous Material

Bitumen shall be heated in a tar boiler to a temperature between 121⁰C and 163⁰C Locally produced, wood fired boilers are satisfactory, and at the ambient temperatures experienced in Bangladesh the 80/100 penetration grade bitumen required under the specification can be poured (albeit slowly) into the tar boiler When the boiler is approximately 30% full the fire box is filled with wood and the wood ignited. In practice the boilers are generally kept over 50% full during operation by allowing up to two drums of bitumen to drain down through a manhole, on top of the boiler into the main heating tank.

The temperature control at the boiler is critical to the success of this methodology. When the thermometer within the mass of bitumen in the main tank reaches 150⁰C the firebox must be emptied or the fire extinguished. The residual heat within the tar boiler will continue to heat the bitumen to the required maximum temperature of 163 ⁰C. When the temperature is falling and reaches 155⁰C the fire box should be refilled with wood and re-ignited as the temperature will soon fall below 150⁰C. The operation is repeated as the temperature again regains 150⁰C. With experience the operator can soon judge how much firewood is required to achieve and maintain the specified temperatures.

3.16.3.3 Preparation of Mineral Aggregate

Once the aggregates and the job mix has been approved, the Contractor shall construct gauging boxes to the required size which, when filled and struck off level, deliver the desired volume for that size of stone.

The pea gravel and sand are batched into a rectangular steel pan with handles at each corner and heated on top of a metal frame under which heating is provided by firewood and sawdust. The mixture is continually raked to ensure thorough mixing and even heating. The temperature of the mixture must reach 163⁰C after which the pan shall be transferred to an unheated frame where raking should continue until the mixture temperature has reduced to the maximum temperature permitted in the specification (163⁰C)

3.16.3.4 Preparation of Premix Seal Coat

The heated bitumen is drawn off from the tar boiler, decanted into gauge tins and added to the aggregate in the pan on the unheated frame in the proportion of 1.0kg of bitumen to 0.01m³ aggregate mixtures, which shall be laid on 1m² of road surface for 7mm thickness seal coat. The proportions will be increased to 1.36kg of bitumen to 0.016m³ of aggregate mixture on 1m² of road surface for 12 mm thickness seal coat. As the two ingredients are at approximately the same temperature there is no risk of fire, overheating or the clouds of black smoke (indicating hot bitumen being applied to very hot aggregates) associated with

other manual methods. The mixing is carried out on the unheated frame and, when satisfactorily completed, the pan is carried to the adjacent work head for placing.

The mixture shall after mixing be at a temperature within the limits of 135°C and 163°C. The Contractor shall record and submit the measured temperatures for the Engineer's approval.

3.16.3.5 Spreading and Compaction

The mixed bituminous seal coat shall be placed and spread over the granular base course which has been primed or bituminous carpeting to a uniform thickness which shall be a minimum of 25% greater than the specified compacted thickness, and immediately compacted with a power-driven road roller to the satisfaction of the Engineer.

Static tandem steel wheel rollers will require trials to assess the number of passes to achieve full compaction. Compaction is generally achieved when all roller marks have been removed. Rollers shall not be allowed to severally achieved material that may be deformed thereby the mixture shall be compacted as soon after being placed as the material will support the roller without undue displacement or cracking and sufficient compaction plant should be deployed so that the required degree of compaction is achieved before the mat has cooled to a temperature of 107°C.

To avoid traffic disruption, the spreading and compaction on sections of existing bituminous surface is often carried out over half the road width only.

Unless the Engineer directs otherwise the seal coat where specified shall be applied immediately after laying of the bituminous carpeting and the seal coat and bituminous carpeting shall be rolled together. The combined thickness of the two layers shall not be less than the sum of the two specified layer thickness.

3.16.3.6 Joints

The work shall be organized so that transverse Joints are kept to a minimum and, where practical, only occur at specified positions (ie. bridges etc.). All transverse joints are to be cut back to well compacted full depth material to produce a straight vertical joint which is to be painted with bitumen before laying of new material.

To attain a strong and even connection in the longitudinal direction, joints shall be pre-heated in front of laying the adjacent bituminous mix. Alternatively, if approved by the Engineer, the joint can be cut back and painted with bitumen.

3.16.3.7 Protection of the Pavement

Sections of the newly finished work shall be protected from traffic of any kind until the mixture has cooled to approximately ambient air temperature. Traffic shall not normally be permitted on the newly laid surface less than 12 hours after completion of the pavement, except with the approval of the Engineer.

3.16.3.8 Pavement Samples

If the seal coat is placed on to the carpet course specified in Section 3.15 the Contractor shall after final rolling and before opening the surface to traffic, cut samples from the

finished work for testing. Samples for the full depth of the course and seal shall be cores with diameters of 100/150 mm as directed, and cut by an approved coring machine, from the locations directed by the Engineer. At least one sample for density and thickness measurement shall be taken for each 50 m of completed surfacing.

When the seal coat is placed over an existing bituminous surfacing samples for analysis and other tests shall be taken from the surfacing when the Engineer so directs.

Where samples have been taken from the surface course, fresh material shall be placed thoroughly compacted and finished to the satisfaction of the Engineer.

3.16.3.9 Surface Texture

The surface finish of the finished surfacing shall be close and tight.

3.16.4 Measurement

The quantity of bituminous seal coat measured for payment shall be the number of square metres completed and accepted to the thickness shown on the Drawings or as directed by the Engineer. Bitumen used in the mix shall be deemed to be included and shall not be measured separately irrespective of its quantity. No price adjustment shall be made if the quantity of bitumen used increases or decreases due to a change in the job mix formula during the works.

3.16.5 Payment

The quantities measured as provided above, shall be paid for at the Contract unit rates. The prices and payments shall be full compensation for furnishing and placing all materials including all labour, equipment, tools, trials, preparation of job-mix formulas, testing, making good test holes, and incidentals necessary to complete the work.

Pay items shall be:

3/16/1	7mm Compacted Premix Bituminous Seal Coat	Square Metre
3/16/2	12mm Compacted Premix Bituminous Seal Coat	Square Metre
3/16/3	15mm Compacted Premix Bituminous Seal Coat	Square Metre

3.17 ASPHALT TREATED BASE USING RECLAIMED ASPHALT PAVEMENT

3.17.1 Scope

This work covers the recycling of existing bituminous pavement materials to upgrade an existing bituminous pavement which has served its initially intended purpose. The work shall be performed on such widths and lengths as may be directed by the Engineer and may consist of pavement removal, stockpiling of materials from the old pavement, addition of new bitumen and untreated aggregates in the requisite proportions, mixing, spreading and compaction of the blended materials.

Recycling processes can be categorized into in-situ recycling (where processing takes place on site), and central plant recycling (where reclaimed material is processed off site). The processes can be further sub-divided into hot and cold processes. This specification covers the hot process only.

3.17.2 Reclaimed Bituminous Materials for Central Plant Recycling

3.17.2.1 Proportion of reclaimed materials less than 10 percent

If not more than 10 percent of reclaimed bituminous material is to be used in the production of Asphalt Treated Base (ATB), then Clauses 3.17.2.2 to 3.17.2.7 and clauses 3.17.5.1 to 3.17.5.4 will not apply. However:

- a) all reclaimed bituminous material shall be pre-treated before use such that the material is homogeneously mixed and the maximum particle size of reclaimed material does not exceed 40 mm.
- b) the mixed material shall comply with the requirements of Clause 3.13 Dense Bituminous Surfacing as appropriate.

3.17.2.2 Proportions of reclaimed materials greater than 10 percent:

Reclaimed bituminous material of an amount greater than 10 per cent, may be used in the Asphalt Treated Base (ATB), subject to the requirements of Clauses 3.17.2.3 to 3.17.2.9 and subject to the satisfactory completion of full trial investigations in respect of all related materials, layer thickness, machine operations and finished works on a case by case basis entirely at the Contractor's cost and subject to the approval of the Engineer. For estimating purposes, a maximum amount not greater than 30 percent reclaimed bituminous material should be assumed.

3.17.2.3 Materials for recycled pavement:

The recycled materials shall be a blend of reclaimed and new materials proportioned to achieve a paving mixture with the specified engineering properties. The reclaimed materials shall be tested and evaluated to find the optimum blend meeting the mixture requirements. Such testing and evaluation shall be carried out on representative sample, either cores sampled from the carriageway or samples taken from stockpiles in accordance with current practice. The sampling frequency should be sufficient to determine how consistent the reclaimed material is and to provide representative samples for composition analysis and measurement of properties of recovered binder. As an absolute minimum, one sample to

represent 500 m two lane carriageway shall be taken. The Reclaimed Asphalt Pavement (RAP) shall meet the technical requirements shown in Table 3.17-1.

Table 3.17-1 Technical requirements for RAP

Recycling method	Material	Test items	Technical requirements	Test method
Hot central plant recycling, RAP after processing	RAP	Water content (%)	≤ 3	
		Maximum particle size(mm)	≤ 40.00	
	RAP under 4.75 mm	Sand equivalent (%)	≥ 60	
	Coarse aggregate in RAP	Percentage of flat and elongated particles (%)	≤ 15	
		Maximum particle size(mm)	$\leq$ Maximum allowed Particle size	
	Asphalt in RAP	Penetration at 25 °C (0.1 mm)	≥ 15	STP 10.1

3.17.2.4 Bitumen extraction

The procedure described in ASTM D-2172 (STP 10.4) shall be used to quantitatively separate aggregates and bitumen from any representative sample of reclaimed bituminous pavement.

3.17.2.5 Aggregate evaluation

Mechanical sieve analysis (wet sieving method) shall be performed on the aggregate portion of the reclaimed bituminous pavement sample to determine the grading. It is essential that the reclaimed materials to be recycled are consistent, as variable materials will cause problems with the control of quality and impede the efficiency of the recycling operation. Suitable sources of consistent material either in existing pavements, from stockpiled of known origin or from another suitable source, before a decision can be made on the optimum percentage of reclaimed material.

After selecting the proportion of reclaimed materials to be recycled, the grading of the mixture may need adjustment, to meet Specification requirements, by the addition of selected aggregate sizes.

3.17.2.6 Evaluation of bitumen:

When the amount of reclaimed bituminous materials to be used in the mixture exceeds 10 percent, the penetration value of the recovered binder from the reclaimed bituminous material, before mixing, shall exceed 15 pens, after recovery of binder in accordance with the requirements of BS:2000: Part 397 (Recovery of bitumen binders), when tested in accordance with STP 10.1. Provided the above requirement is met, hardening of the old binder, during the original mixing process or through ageing, can be compensated for by adding softer bitumen, to obtain the appropriate final grade of binder.

The determination of the type and amount of binder required to be added in the final mix is essentially a trial and error procedure.

3.17.2.7 Rejuvenators

Rejuvenator can be added to recycled hot mix asphalt or hot asphalt treated base course to recover penetration and other properties of the old asphalt. These do not include new asphalt. Standard properties for rejuvenator are as shown in Table 3.17-2.

Beside these, there are additives with a modifying effect, added to improve the properties of hot mix asphalt to the equivalent of modified asphalt mixture. In these cases, it is recommended that the respective recycled asphalt and recycled hot mix asphalt properties for mixability, workability, serviceability, etc. are confirmed before use.

However, rejuvenator used in excess may lead to severe loss of properties for recycled material, especially remarkably with repeatedly recycled asphalt material. Therefore, care should be taken against excess use of rejuvenator in consideration of future repeated recycling of the product.

Table 3.17-2 Standard properties for rejuvenator

Item		Standard property
Kinematic viscosity (60°C)	mm ² /s	80-1,000
Flash point	°C	250 or more
Viscosity ratio after thin-film heating	(60°C)	2 or less
Loss on thin-film heating	%	Within ± 3
Density (15°C)	g/cm ³	≥ 0.95

3.17.2.8 Untreated aggregates:

If necessary, fresh untreated aggregates shall be added to the reclaimed bituminous pavement to produce a mix with the desired grading. The aggregate shall be checked for quality requirements in accordance with 3.8.2.1, 3.8.2.2 and 3.8.2.3. Reclaimed aggregate, if any, or any aggregate normally used for the desired bituminous mix, or both, may be used for this purpose.

3.17.2.9 Combined aggregate grading:

The blend of reclaimed and new aggregate shall meet the grading criteria specified in Table 3.17-3

Table 3.17-3 Grading requirements for Asphalt Treated Base (ATB)

Grading	1	2
Nominal aggregate size	37.5 mm	26.5 mm
Layer thickness	75-100 mm	50-75 mm
Sieve (mm)	Cumulative % by weight of total aggregate passing	
45	100	
37.5	95-100	100
26.5	63-93	90-100
19	-	71-95
13.2	55-75	56-80
9.5	-	-
4.75	38-54	38-54
2.36	28-42	38-54
1.18	-	-
0.6	-	-
0.3	7-21	7-21
0.15	-	-
0.075	2-8	7-21
Bitumen content % by mass of total mix	Min 4.0	Min 4.5

3.17.3 Mixture Design

Modified Marshall Method described in MS-2 of Asphalt Institute and ASTM D5581 shall be used. Chapter 11 of MS 2 may be followed. The mix design shall comply with the requirements of Table 3.18-4

Table 3.17-4 Requirements for Asphalt treated base (ATB)

Properties	Requirements
Compaction level	112 blows on each face of the specimen
Minimum Stability (kg at 60°C)	1800
Marshall flow (mm)	3-5
% air voids	3-5
% voids filled with bitumen	65-75
% voids in Mineral aggregate VMA	10-12

3.17.4 Reclaiming Old Pavement Materials

The removal of pavement materials to the required depth shall be accomplished either at ambient temperature (cold process) or at an elevated temperature (hot process), as approved by the Engineer.

3.18.4.1 Cold removal process:

In the cold process, the ripping and crushing operations shall be carried out using scarifiers, grid rollers, or rippers or by any other means as directed by the Engineer.

The removed materials shall be loaded and hauled for crushing to the required size as directed by the Engineer. Alternatively, cold milling or planning machines can be used to

reclaim bituminous pavement to controlled depths. Thereafter the bituminous layers are removed, any remaining aggregate materials that are to be incorporated in the recycled hot mix shall be scarified and removed. When the pavement material removal is completed, any drainage deficiencies shall be corrected. After that, the base/sub-base as the case may be shall be cut, graded and compacted to the required profile and density.

3.18.4.2 Hot removal process:

In the hot process, the road surface shall be heated, by any suitable means approved by the Engineer, before scarification. A self propelled plant shall be used, and a milling drum that follows the planer removes the heated soft bituminous layer. The depth, width and speed of travel shall be adjusted to suit specific requirements as directed by the Engineer. During the heating process, the surface temperature of the road shall not exceed 200°C for more than 5 minutes.

3.18.4.3 Stockpiling:

In the cold process, the reclaimed bituminous pavement material shall be stockpiled with height of stockpiles not exceeding 3 m. The reclaimed untreated aggregate base/sub-base material shall be stockpiled in the same manner as new aggregate. The number and location of stockpiles shall be carefully planned for efficient operation of the hot-mix plant. Processed RAP shall be separated and stockpiled according to different material sources, types and specifications; and a clear sign for materials shall be set up respectively. It shall be laid out horizontally and stockpiled layer by layer. Processed RAP should not be stored for a long time; segregation and agglomeration shall be avoided.

3.18.5 Construction Methods

Construction methods shall conform to the requirements of section 3.13.3 of these specifications subject to the following modifications.

3.18.5.1 Equipment requirements

Production equipment for hot central plant recycling shall meet the following requirements:

1. Equipped with no less than 2 RAP cold bins;
2. Equipped with independent RAP heating drum, and temperature measuring device shall be put at the RAP heating drum discharge port, while the accuracy of temperature measurement should not be lower than $\pm 3^{\circ}\text{C}$;
3. Equipped with independent RAP hot bin for temporary storage, and the bin shall have heating functions and should have monitoring device about the remaining amount of material;
4. Equipped with RAP dosing device and metering device, and the static-weighting accuracy should not be lower than $\pm 0.5\%$;

5. Feeding capacity of the RAP supply system, the heating capacity of the burner, and production capacity of RAP heating drum shall meet maximum production capacity requirements of equipment;
6. For the heating device, the RAP shall not contact with the flame directly;
7. A special device shall be installed inside the RAP heating drum to prevent the RAP from sticking to the inner wall of the roller;
8. Storage, metering and spraying devices of the rejuvenating agent shall be equipped as needed. The static weighing accuracy of the rejuvenating agent should not be lower than $\pm 0.3\%$.

3.17.5.2 Mix

Mixing time of recycled mixtures shall be determined by trial mixing according to specific conditions, and the mixed mixtures shall be uniform and without uncoated particles. The dry mixing time should be extended by 5-10 s compared with ordinary hot mix asphalt, and total mixing time should be extended by 10-30 s compared with ordinary hot mix asphalt. The mixing time in each stage should be within limits specified in Table 3.17-5

Table 3.17-5 Mixing time of hot central plant recycling asphalt mixtures

Items	RAP	Rejuvenating agent	New aggregate	Virgin asphalt	Mineral filler
Mixing time (s)	10-15		10-15	15-20	20-25
Total mixing time (s)	55-75				

Production temperature of recycled mixtures shall meet the following requirements:

1. The heating temperature of new aggregate shall be increased appropriately during mixing, but its maximum temperature should not exceed 200 °C.
2. The heating temperature of RAP should not be lower than 110 °C, and not higher than 130 °C.
3. Discharging temperature of recycled mixtures shall be 5-10 °C higher than that of corresponding hot mix asphalt.
4. RAP shall be prevented from overheating or insufficient heating during the mixing process. RAP shall be discarded when it becomes overheated or carbonized.

3.17.5.3 Paving

Paving temperature of recycled asphalt mixtures should be 5-10 °C higher than that of hot mix asphalt. Loose mixtures to compacted mat thickness ratio of recycled mixtures shall be determined by test strip. Preheating temperature of paver screed shall not be lower than 110°C.

3.17.5.4 Compaction

The compaction temperature of recycled mixtures should be 5-10 °C higher than the corresponding compaction temperature basis of hot mix asphalt specified in Table 3.8-3.

Roller should compact against supporting and retaining edge when there are baffles, curbs, unfilled pavement as supports. Wheel of roller should extend over 100 mm out the edge for compaction when there is no supporting or confining edge.

The straight-line compaction should be adopted for a sharply curved section, and the small-sized machine should be used for corners where roller may not compact.

3.17.5.5 Quality control

Processed RAP and rejuvenating agent shall be inspected in batches before construction, and their properties shall conform to the requirements the Specifications. Quality inspection of processed RAP during the construction process shall be carried out in accordance with requirements in Table 3.17-6

Table 3.17-6 Test frequency and quality requirements on processed RAP during hot central plant recycling

Test items		Frequency	Quality requirements or allowable deviations
Water content (%)		Once a working day	≤ 3
The aggregate bulk specific gravity of RAP		1 time/5000: RAP	Actual measurement
RAP aggregate gradation	Passing percentage 0.075 mm (%)	1 time/2000 t RAP	± 2
	Passing percentage above 0.075 mm (%)	1 time/2000 t RAP	± 4
RAP asphalt	Content (%)	1 time/2000 t RAP	± 0.5
	Penetration at 25 °C (0.1mm)	1 time/5000 t RAP	± 5

3.17.5 Measurement

The quantities of dense bituminous pavement with PMB measured for payment shall be the number of cubic metres of accepted and completed surfacing, of the widths and thickness shown on the Drawings. However, the Contractor should allow in his rates for additional material used for forming sloping edges, waste, over spill, joints, cut- backs etc. Should the widths and/or thickness of completed and accepted surfacing be less than indicated on the Drawings, the quantities measured for payment will be based on the actual widths and/or thickness. No adjustment in payment will be made where the pavement widths and thickness as laid and approved are greater than those specified.

The surface profiles of courses will be used in the measurement of course thickness, unless an alternative method, such as core thickness, is approved by the Engineer.

3.17.6 Payment

The quantities of dense bituminous surfacing with PMB measured as provided above shall be paid for at the Contract unit rates. The rates and payments shall be full compensation for furnishing and placing all materials including all labour, equipment, tools, trials, preparation of job-mix formulae, testing, making good test holes and all incidentals necessary to complete the work. Tack coat shall not be paid for separately except where specifically provided in the Contract Documents.

When Tack Coat is included as a separate BoQ item in the Contract Document, but the quantity is not sufficient to cover all the bituminous works under the BoQ, the cost of quantity of Tack Coat required in addition to the BoQ provision shall be considered to be included within the rates of bituminous layer. The contractor is advised to make necessary adjustments accordingly in his rates of bituminous layers.

Pay item shall be:

3/17/1 Asphalt Treated Base Course

Cubic Meter

3.18 RECYCLED WEARING COURSE

3.18.1 Description

This work shall consist of rehabilitation of deteriorated bituminous wearing course by Hot in-place Recycling (HIR) method in accordance with these specifications, to the lines, levels, grades, dimensions and cross sections shown on the Drawings, or as required by the Engineer. The existing wearing course is scarified, mixed with additional materials, if required and compacted as soon as possible after spreading. The total compacted thickness is typically up to 50mm.

3.18.2 Heating and Scarifying

The surface to be treated shall be heated by an enclosed, insulated plant. The heated width shall exceed the scarified width by at least 75 mm on each side, except adjacent to kerbs or carriageway edges.

Any new surfacing material spilled on the road before heating shall be removed. Un-scarified areas shall not exceed 50 mm × 50 mm.

The depth of scarification shall be such that the bottom of the scarified layer lies parallel to and below the final surface level by the thickness of the specified wearing course, with a tolerance of ±6 mm.

Street furniture and other obstructions shall be protected or removed before heating. Surface dressing and large areas of road markings shall be removed by milling, planning, or approved equivalent methods.

During heating, the surface temperature shall not exceed 200°C for more than five minutes.

3.18.3 Rejuvenator

The use of rejuvenators and the tests to determine their effectiveness shall be carried out in accordance with the provisions of Section 3.17.2.7 and Table 3.17-2.

When required, rejuvenator shall be uniformly sprayed across the full width of the processed material. The spraying equipment shall include a calibrated meter to verify the applied quantity within ±5% of the specified rate. The application rate shall vary according to the operating speed of the machine and the volume of material processed. The rejuvenator shall be a non-emulsified aromatic extract, with its properties verified using the Rolling Thin Film Oven Test (RTFOT). After using rejuvenators, the penetration value of the binder will be minimum 60.

3.18.4 Additional Material

Additional material such as coarse aggregate, fine aggregate, mineral filler etc shall be used to meet the grading requirements of wearing course given in Table 3.13-1. Any additional coarse aggregate, fine aggregate, mineral filler, bitumen etc. used shall conform to the requirements of Clause 3.13.2 and 3.14.2.

3.18.5 Plant and Equipment

The equipment consists of a preheating unit, a heating and recycling unit, and a rubber-tired roller. The preheating unit heats up the old HMA pavement surface, the heating and recycling unit applies more heat and scarifies the HMA pavement with a set of non-rotating teeth, and sprays the recycling agent. Then the old pavement and recycling materials are mixed with a standard auger, and leveled off with a screed. A rubber-tired roller is used for compacting the recycled mix.

3.18.6 Mixing, Laying and Compaction

When required, additional material shall be mixed with the heated and scarified pavement material in a pug mill within the remix machine, maintaining the temperatures specified in Table 3.8-3. Mix design procedure as mentioned in chapter 11 of MS 2-2014 shall be followed. The new asphalt concrete wearing course shall comply with Clause 3.13.1.2 or 3.14.1.1 as applicable. After mixing, the recycled material shall be automatically transferred to a finishing unit, which spreads and levels the mixture to the specified thickness and cross-section. It shall be laid over and compacted with the re-profiled surface while maintaining a temperature range given in Table 3.8-3.

3.18.7 Sample collection for Quality control

Samples for mix design shall be taken from the paver hopper or augers, ensuring only material forming the new surface layer is collected. Each sample shall be reduced to approximately 5 kg by riffing or quartering and stored in an air-tight container. The sample shall be reheated only once, remixed, and used to prepare three Marshall Specimens in accordance with MS-2. The bulk density, Marshall Stability, and flow values shall meet the requirements of Table 3.13-2 and 3.13-3. The combined specimens shall be tested for maximum theoretical specific gravity (G_{mm}) as per ASTM D2041. The air void content (V_a) shall be determined using:

$$[(G_{mm}-G_{mb})/G_{mm}]*100$$

Where, G_{mb} is the measured bulk specific gravity. The calculated air voids shall comply with the limits specified in Table 3.13-2.

Binder samples shall be recovered from each layer of laid material in accordance with BS:2000 Part 397 or an equivalent standard. The penetration value of the recovered binder shall be within the range of 60–70 pen.

3.18.8 Opening to Traffic

Provisions of Clause 3.13.3.7 shall apply.

3.18.9 Measurement for Payment

Recycled pavement work shall be measured in cubic meters of finished work.

3.18.10 Payment

The contract unit rate for recycled pavement shall be full compensation for all operations required under this specification, including all materials, labour, equipment, and incidentals necessary to complete the work. No additional payment will be made for additional material described in 3.18.3, 3.18.4. Contraction shall take in account all additional materials required in quoting the price of this item.

Pay item shall be:

Item 3/18/1 Recycled wearing course

Cubic metre

3.19 STONE MATRIX ASPHALT (SMA)

3.19.1 Scope

This work shall consist of construction in a single or multiple layer of fiber-stabilized SMA on a previously prepared bituminous bound surface. SMA is based on the concept of designing a coarse aggregate skeleton so that stone-on-stone contact is obtained, which provides a highly rut-resistant bituminous course for heavy traffic roads. The 13mm SMA in this Specification is intended for wearing course with nominal layer thickness of 40 to 50mm. The 19mm SMA is intended for binder (or intermediate) course with nominal layer thickness of 45 to 75 mm.

3.19.2 Materials

3.19.2.1 Bitumen:

The bitumen for fibre-stabilized shall be polymer grade bitumen complying with AASHTO M320 and AASHTO M 332. The PMB Grades will be selected based on the highest and lowest pavement temperatures and the type of traffic at the project site as per AASHTO M332.

3.19.2.2 Coarse aggregates:

The coarse aggregates shall consist of crushed rock retained on 2.36mm sieve. It shall be clean, hard, durable of cubical shape and free from dust and soft organic and other deleterious substances. The aggregates shall satisfy the physical requirements given in Table 3.19-1.

Table 3.19-1 Physical Requirements for Coarse aggregates for Stone Matrix Asphalt

Property	Test	Method	Specification
Particle Shape	Flakiness Index	STP 7.3.1	<12%
	Elongation Index	STP 7.3.1	<18%
Strength	Los Angeles Abrasion Value (LAA)	AASHTO T104	<25%
	Aggregate Impact Value (AIV)	BS 812-112	<18%
Polishing*	Polished Stone Value	BS EN 1097-8	>55%
Durability	Soundness Sodium Sulphate-5cycles	AASHTO T104	<10%
	Soundness Magnesium Sulphate -5cycles	AASHTO T104	<18%
Water Absorption	Water Absorption	STP 7.5.4	<2%

*Polishing requirement does not apply when the coarse aggregate is used in the 19mm SMA, which is used as an intermediate (binder) course.

3.19.2.3 Fine aggregates:

Fine aggregates (passing 2.36 mm sieve and retained on 0.075 mm sieve) shall consist of 100 percent crushed, manufactured sand resulting from crushing operations. The fine aggregate shall be clean, hard, durable, of fairly cubical shape and free from soft pieces, organic or other deleterious substances. The Sand Equivalent Test value for the fine aggregate shall not be less than 50. The fine aggregate shall be non-plastic.

3.19.2.4 Mineral filler:

Mineral filler shall consist of finely divided mineral matter such as stone, dust and/or hydrated lime. Fly ash will not be permitted as filler in SMA. The filler shall be graded within the limits indicated in Table 3.1-2.

Table 3.19-2 Grading Requirement of Mineral Filler

Sieve (mm)	Cumulative % passing by weight of total aggregate
0.6	100
0.3	95-100
0.075	85-100

The filler shall be inert material free from organic impurities and shall have plasticity index not greater than 4. Plasticity Index requirement will not apply if filler is hydrated lime. Where the complete SMA mixture fails to satisfy the requirement of Moisture Susceptibility Test (AASHTO T 283), at least 2 percent by total weight of aggregate of hydrated lime shall be used and the percentage of fine aggregate reduced accordingly.

3.19.2.5 Stabilizer additive:

Only pelletized cellulose fibers shall be utilized. The dosage rate for cellulose fibers is 0.3 percent minimum by weight (on loose fiber basis) of the total mix. The dosage rate shall be confirmed so that the bitumen drain down does not exceed 0.3 percent when the designed mix is tested in accordance with ASTM D 6390.

The cellulose fibers to be used in pellets shall meet the following requirements:

Maximum fiber length	- 8mm
Ash content	- maximum of 20 percent nonvolatile
absorption	- Oil
Moisture content	- more than 4 times of the fiber weight
	- less than 5 percent by weight

When the contractor submits the proposed job-mix formula for SMA for approval, it shall include the fiber manufacturer's most recently dated actual test data showing the fibers meet the above requirements. The Contractor shall protect the cellulose from moisture and contamination prior to incorporating it into the SMA.

3.19.3 Sma Mix Design

3.19.3.1

The combined grading of the coarse aggregate, fine aggregate and mineral filler (including hydrated lime if used) shall be within the limits shown in Table 3.19.3.

Table 3.19-3 Composition of Stone Matrix Asphalt

SMA Designation	13 mm SMA	19 mm SMA
Course where used	Wearing course	Binder (intermediate) course
Nominal aggregate size	13mm	19mm
Nominal layer thickness	40-50mm	45-75mm
Sieve(mm)	Cumulative% by Weight of total aggregate passing	Cumulative % by weight Of total aggregate passing
26.5	-	100
19	100	90-100
13.2	90-100	45-70
9.5	50-75	25-60
4.75	20-28	20-28
2.36	16-24	16-24
1.18	13-21	13-21
0.600	12-18	12-18
0.300	10-20	10-20
0.075	8-12	8-12

Bailey Method of Gradation can be followed to achieve aggregate to aggregate contact. Degradation of aggregates shall be checked by conducting grading before and after Marshall test and grading shall be adjusted.

3.19.3.2

The SMA mixture will be designed using AASHTO M325-08 Standard Specification for Stone Matrix Asphalt (SMA) and AASHTO R 46-08 Designing Stone Matrix Asphalt (SMA). The outline of mix design of SMA is given in sections 4.6 through 4.9. The SMA mixture shall be compacted with 50 blows on each side using the Marshall procedure given in the Asphalt Institute MS-2 (7th Edition-2014). The designed mix shall meet the requirements given in Table 3.19-4.

SMA mix may be designed at 50 Marshall blows; however, the mix designed at this compaction level in the laboratory may be compacted to a lower air void content in the field. When using the Marshall compaction in the mix design procedure, this effect needs to be considered or the design may be performed at blows other than 50 (both sides) to get air void more than 2.5 %. The Pavement Quality Indicator (PQI) or Nuclear Density Gauge (NDG) will be used during construction for maintaining air void in field and field air void shall be below 6 %. Air void of mix may be checked at 350 gyration if facility is available and air void should exceed 2.5 %.

For heavy traffic (>30 MSA) mix design may be carried out at 5 or close to 5 % air void but field air void should be less than 6%.

Table 3.19-4 SMA Mix requirements

Mix design parameters	Requirement
Air void content, percent	4.0
Bitumen content, percent	5.8min.
Celluloid fibres	0.3 percent minimum by weight of total mix
Voids in mineral aggregate (VMA), percent	17min.
VCA mix, percent	Less than VCA (dry rodded)
Asphalt draindown, percent AASHTO T 305 (Annex C)	0.3 max.
Tensile Strength Ratio (TSR), percent AASHTO T 283(Annex D)	85 min

3.19.4 SMA Production

3.19.4.1 Mixing:

The SMA mix shall be prepared in a hot mix plant of adequate capacity and capable of yielding a mix of proper and uniform quality with thoroughly coated aggregate.

PMB will be only used as binder. The storage, handling and application of PMB for SMA mix is given below. In order to ensure uniform quality of mix, the plant shall be calibrated from time to time.

For short term storage (3-4 days), the recommended temperature is around 165-170°C.

For long term storage (up to 2 weeks), the recommended temperature is 140-150°C

For very long-term storage (more than 2 weeks), the recommended temperature is below 100°C.

The recommended pump able unloading temperature for PMB is above 150°C.

Mixing with aggregates 177-180°C

Laying 165-170°C

Compaction over 150°C

End of compaction 115-120°C

3.19.4.2 Handling mineral filler:

Adequate dry storage will be provided for the mineral filler and provisions shall be made for proportioning the filler into the mixture uniformly and in the desired quantities. This is necessary because relatively large amounts of mineral filler are required in SMA mixes.

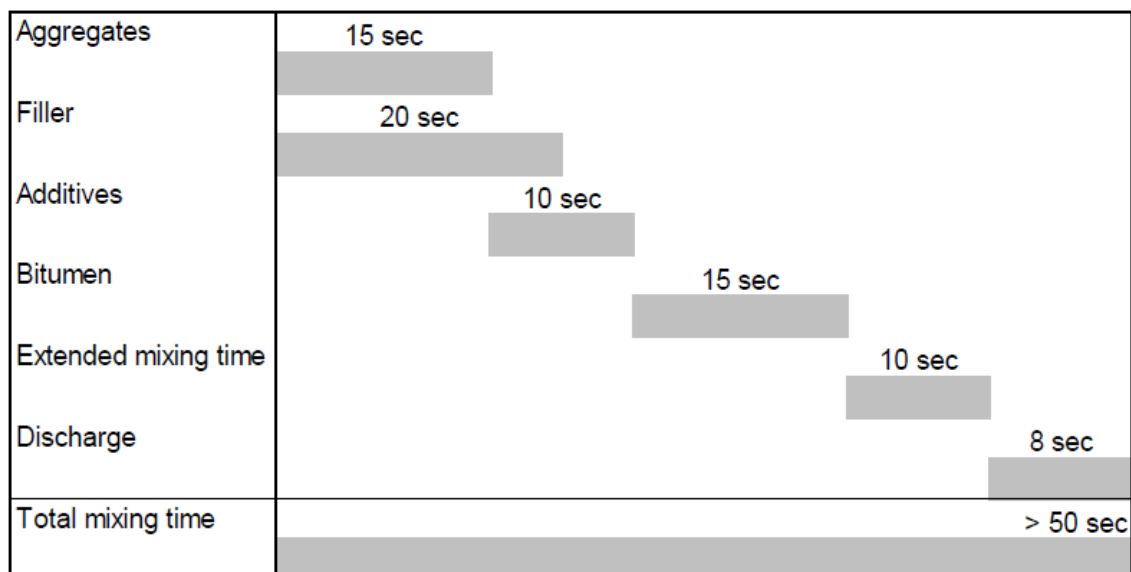
3.19.4.3 Fibre additive:

For batch plant, the fiber will be added directly into the weigh hopper above the pugmill. Adequate dry mixing time is required to disperse the fiber uniformly throughout the hot aggregate. Dry mixing time will be increased by 5 to 10 seconds. Wet mixing time shall be increased by at least 5 seconds. For drum mix plant, a separate fiber feeding system shall be utilized that can accurately and uniformly introduce fiber into the drum at such a rate

as not to limit the normal production of mix through the drum. At no time shall there be any evidence of fiber in the bag house/wasted bag house fines.

3.19.4.2 For batch plant, the fiber will be added directly into the weigh hopper above the pugmill. Adequate dry mixing time is required to disperse the fiber uniformly throughout the hot aggregate. Dry mixing time will be increased by 5 to 10 seconds. Wet mixing time shall be increased by at least 5 seconds. For drum mix plant, a separate fiber feeding system shall be utilized that can accurately and uniformly introduce fiber into the drum at such a rate as not to limit the normal production of mix through the drum. At no time shall there be any evidence of fiber in the baghouse /wasted bag house fines.

A flow Diagram and sequence for plant mixing is shown below and this shall be followed during preparation of Plant Mixing of all Ingredients and minimum mixing time shall be more than 50 Seconds



3.19.5 SMA Placement and Compaction

3.19.5.1 Preparation of existing bituminous surface:

The existing bituminous surface shall be cleaned of all loose extraneous matter by means of mechanical broom and high-pressure air jet from compressor or any other approved equipment/method. Any potholes and/or cracks shall be repaired and sealed.

3.19.5.2 Tack Coat: Clause 3.10 shall apply.

3.19.5.3 Transportation:

The SMA Shall be transported in clean insulated covered vehicles. An asphalt release agent which does not adversely affect the bituminous mix should be applied to the interior of the vehicle to prevent sticking and facilitate discharge of the material. The use of MTV (Material Transfer Vehicle) shall be used if so specified in the contract.

3.19.5.4 Weather and seasonal limitations:

Laying shall be suspended:

- In presence of standing water on the surface;
- When rain is imminent and during rains, fog or dust storm;
- When the base/binder course is damp;
- When the air temperature on the surface on which it is to be laid is less than 10°C for mix with conventional bitumen as binder and is less the 15°C for mix with modified bitumen as binder;
- When the wind speed at any temperature exceeds the 40 km per hr at 2m height.

3.19.5.5 Spreading:

Prior to spreading the mix, the base shall be prepared by carrying out all or some of the operations depending upon the site conditions. Except in areas where paver cannot get access, SMA shall be spread, leveled and tamped by an approved self-propelled paving machine preferably with sensor. As soon as possible after arrival at site, the materials shall be supplied continuously to the paver and laid without delay. The rate of delivery of material to the paver shall be regulated to enable the paver to operate continuously. The travel rate of the paver, and its method of operations, shall be adjusted to ensure an even and uniform flow of SMA across the screed, free from dragging, tearing and segregation of the material. In areas with restricted space (such as confined space, foot base, irregular shape and wearing thickness, approaches to expansion joints, etc.) where paver cannot be used, the material shall be spread, raked and leveled with suitable hand tools by trained staff. The minimum thickness of material laid in each paver pass shall be in accordance with the minimum values given in the relevant parts of these Specifications. When laying SMA approach an expansion joint of a structure, machine laying shall stop 300 mm short of the joint. The remainder of the pavement up to the joint, and the corresponding area beyond it, shall be laid by hand, and the joint or joint cavity shall be kept clear of surfacing material.

3.19.5.6 Compaction:

SMA shall be laid and compacted in layers, which enable the specified thickness, surface level, regularity requirements and compaction to be achieved.

Compaction of SMA shall commence as soon as possible after laying. Compaction shall be substantially completed before the temperature falls below the minimum rolling temperatures stated in the relevant part of these Specifications. Rolling of the longitudinal joints shall be done immediately behind the paving operation. After this, rolling shall commence at the edges and progress towards the center longitudinally except that on super elevated and unidirectional cambered portions, it shall progress from the lower to the upper edge parallel to the center line of the pavement. Rolling shall continue until all roller marks have been removed from the surface. All deficiencies in the surface after laying shall be made good by the attendants behind the paver, before initial rolling is commenced. The initial or breakdown rolling shall be done with 8-10 tonne dead weight smooth-wheeled rollers. The intermediate rolling shall be done with 8-10 tonne dead weight or vibratory roller or with a pneumatic tyred roller of 12 to 15 tonne weight having nine wheels, with a

tyre pressure of at least 5.6 kg/sq.cm. The finish rolling shall be done with 6 to 8 torine smooth wheeled tandem rollers.

Where compaction is to be determined by density of cores, the requirements to prove the performance of rollers shall apply in order to demonstrate that the specified density can be achieved. In such cases the Contractor shall nominate the plant, and the method by which he intends to achieve the specified level of compaction and finish at temperatures above the minimum specified rolling temperature. Laying trials shall then demonstrate the acceptability of the plant and method used.

SMA layer shall be rolled in a longitudinal direction, with the driven rolls nearest the paver. The roller shall first compact material adjacent to joints and then work from the lower to the upper side of the layer, overlapping on successive passes by at least one-third of the width of the rear roll or, in the case of a pneumatic-tyred roller, at least the nominal width of 300 mm.

In portions with super-elevated and uni-directional camber, after the edge has been rolled, the roller shall progress from the lower to the upper edge.

Rollers should move at a speed of not more than 5 km per hour. The roller shall not be permitted to stand on pavement which has not been fully compacted, and necessary precautions shall be taken to prevent dropping of oil, grease, petrol or other foreign matter on the pavement either when the rollers are operating or standing. The wheels of rollers machine shall be in good working order, to prevent the mixture from adhering to the wheels. Only sufficient moisture to prevent adhesion between the wheels of rollers and the mixture should be used. Surplus water shall not be allowed to stand on the partially compacted pavement.

3.19.5.7 Joints:

Where joints are made, the material shall be fully compacted and the joint made flush in one of the following ways; All joints shall be cut vertical to the full thickness of the previously laid mix. All loosened material shall be discarded and the vertical face be coated with any viscosity grade bitumen, or cold applied emulsified bitumen. While spreading the material along the joint the material spread shall overlap 25 mm to 50 mm on the previously laid mix beyond the vertical face of the joint. The thickness of the loose overlap material should be approximately a quarter more than the final compacted thickness. The overlapped mix should be dragged back to the hot lane so that the roller can press the small excess into the hot side of the joint to obtain a high joint density.

By using two or more pavers in echelon, where this is practicable and in sufficient proximity for adjacent widths to be fully compacted by continuous rolling.

All joints shall be offset at least 300 mm from parallel joints in the layer beneath or as directed, and in a layout approved by the Engineer. Joints in the wearing course shall coincide with either the lane edge or the lane marking, whichever is appropriate. Longitudinal joints shall not be situated in wheel track zones.

For transverse joints method a) above shall apply. Transverse joints in the successive and adjoining layers shall have a minimum offset of 2 meters.

3.19.5.8 Arrangement for traffic:

It shall be ensured that traffic is not allowed on the SMA surface until the paved mat has cooled to ambient temperature in its entire depth.

3.19.5.9 Controls

All standard control of bituminous pavement construction on surface finish, surface evenness and surface roughness shall apply.

The density of the finished paving layer shall be determined by taking 150 mm diameter cores. The density of finished paving layer shall not be less than 94 percent of the average theoretical maximum specific gravity of the loose mix obtained on that day in accordance with AASHTO T 209. That is, no more than 6 percent air voids shall be allowed in the compacted SMA mat.

3.19.6 Measurement

The contract unit rate for SMA shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause of the General Specification.

3.19.7 Measurement for Payment

The quantities of stone mastic asphalt measured as provided above shall be paid for at the Contract unit rates. The rates and payments shall be full compensation for furnishing and placing all materials including all labour, equipment, tools, trials, preparation of job-mix formulae, testing, making good test holes and all incidentals necessary to complete the work. Tack coat shall not be paid for separately except where specifically provided in the Contract Documents.

Pay items shall be:

3/219/1	Stone Matrix Asphalt	Cubic Meter

3.20 SLURRY SEAL

3.20.1 Description

Slurry seals are mixtures of fine aggregate, additives, slow setting cationic bitumen emulsion and additional water. Different types of slurry seal and their application is given in Table 3.20-1. This treatment shall be used for preventive maintenance and renewal treatment as substitute to surface dressing, premix carpet or mix seal surfacing for low traffic roads.

Table 3.20-1 Different Types of Slurry Seals

Items	Type I (2 – 3mm)	Type II (4 – 6mm)	Type III (6 - 8mm) **
Application	Filling of hair cracks	Filling of surface cracks 1-3mm and preventive/renewal treatment (upto 450 CVPD)***	Filling of surface cracks 3- 6 mm and preventive/ renewal treatment (upto 1500 CVPD)
Quantity* of slurry (Kg /sq m)	4.3 to 6.5	8.4 to 9.8	10.1 to 12
Residual binder (% by weight of dry aggregate)	10 to 16	7.5 to 13.5	6.5 to 12

* In terms by weight of dry aggregate; ** Indicative only; *** Commercial Vehicle per Day.

3.20.2 Materials

The materials for slurry seal immediately prior to mixing shall conform to the following requirements.

3.20.2.1 Emulsified bitumen:

The emulsified bitumen shall be a cationic slow setting type CSS-1h as approved by the Engineer, conforming to the requirements of ASTM D2397 given in Table 3.7-8.

3.20.2.2 Aggregates:

The mineral aggregates shall be crushed stone dust, clean, sharp, hard, durable, uncoated dry particle free from soft pieces and organic and other deleterious substances. The aggregate shall satisfy the requirement given in Table 3.20-2. The target grading shall conform to one of the three types given in Table 3.20-3. The aggregates shall meet the requirements of the film stripping test (**AASHTO T 182**). In case not meeting the requirement, a suitable amount and type of anti-stripping agent, as required to be added.

Table 3.20-2 Properties of Aggregates

Properties	Test Method	Specification
Sand equivalent	AASHTO T 176 / ASTM D 2419	Min 50 percent
Water absorption	AASHTO T 85	Max 2 percent
Soundness with; Sodium sulphate	AASHTO T 104	Max 12 percent
Magnesium sulphate		Max 18 percent

Table 3.20-3 Aggregate Grading, Binder Content and Approximate Coverage Rate

Sieve Size(mm)	Percentage by mass passing Finished thickness of sealing		
	Type I	Type II	Type III
9.5	---	--	100
6.3	---	100	90–100
4.75	100	90–100	70–90
2.36	90–100	65–90	45–70
1.18	65–90	45–70	28–50
0.600	40–65	30–50	19–34
0.300	25–42	18–30	12–25
0.150	15–30	10–21	7–18
0.075	10–20	5–15	5–15

3.20.2.3 Filler:

Mineral filler shall be ordinary Portland cement. The quantity of filler shall be preferably in the range of 0.5 percent to 2 percent by weight of dry aggregate.

3.20.2.4 Water:

Water shall be of potable, free from harmful salt and contaminants. The pH of the water must lie in the range of 6 to 7.

3.20.2.5 Additives:

Chemical additives may be used to accelerate or retard the break-set time of the slurry or to improve the resulting surface finish. The quantity of additive, if used, shall be decided by mix design and to be adjusted as per the site/ climate conditions.

The specifications for additive shall be supplied by the supplier of the emulsion. The additive and emulsion shall be compatible with each other.

3.20.3 Mix Design

The compatibility of aggregate, emulsion, filler and additive (if needed) shall be verified by mix design for a selected type and grading of aggregate as specified in Tables 3.20-2 and

3.20-3. The design criteria for slurry seal mixture is specified in Table 3.20-4 The proposed slurry seal mix shall conform to the specified requirements, when tested in accordance with tests specified in ASTM D 3910-98. The mix design report shall clearly show the proportions of aggregate, filler, water and residual bitumen content based on the dry weight of the aggregates, additive usage (if any).

Table 3.20-4 Mix Design Criteria for Slurry Seal Mix

Requirement	Specifications	Test Method
Mix Time, minimum	180seconds	ASTM- D 3910: 2021
Consistency, maximum	3cm	
Wet cohesion, pass% minimum	20kg.cm	
Wet striping, Pass% , minimum	90	
Wet Track abrasion loss, (one hour soak), maximum	800g/m ²	

Aggregate, bitumen emulsion, water and additive including set control additive (if needed), shall be proportioned by weight utilizing the mix design approved by the Engineer. The final mixture, after addition of water and additive (if used) shall be such that the slurry seal mixture has proper workability and permit traffic within four hours (without leading to raveling after placement). Trial mix shall be prepared and laid at site for the designed mix and observed for breaking and setting time. Indicative limits of various ingredients for job mix of slurry seal shall be as given in Table 3.20-5.

3.20.4 Construction

3.20.4.1 Weather and seasonal limitations:

Laying of slurry seal shall not be undertaken, if either the pavement temperature or air temperature below 10°C. However, during a dry spell, slurry seal may be laid in rainy season also, even if the surface is wet but there is no stagnant water on the pavement surface.

Table 3.20-5 Indicative Quantity of Ingredients

Ingredients	Limits(Percent by weight of dry aggregates)
Cationic Bitumen Emulsion	10 to 16 for Type I 7.5 to 13.5 for Type II 6.5 to 12 for Type III
Water	6 to 12
Filler	1.0 to 2.0
Additive	0.5 to 2.0

Tolerances: Percent passing each sieve shall not vary by more than the tolerance limit indicated in Table 3.20-6 and shall remain within the gradation band.

Table 3.20-6 Tolerances for Slurry Seal

Description	Tolerance
Aggregate passing 4.75 mm	+5%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	+5%
Aggregate passing 0.3mm	+4%
Aggregate passing 0.15mm	+3%
Aggregate passing 0.075mm	+2%

3.20.4.1 Surface preparation:

The underlying surface on which the slurry seal is to be applied shall be cleaned of all loose material, mud spots, vegetation and extraneous matter and shall be prepared and shaped to the needed profile. It is essential to pre-treat cracks on the pavement surface with an appropriate crack sealing material prior to application of slurry seal, if it is used for renewal treatment. The surface should be swept clean by removing caked earth and other foreign matter with wire brushes, sweeping with mechanical brooms and finally dusting with air jet or other means approved by the Engineer

3.20.4.2 Application of tack coat:

Tack coat is not required normally for flexible pavements, unless surface is extremely hungry and dry. In case, it is needed, Clause 3.10 shall apply.

3.20.4.3 Machine:

- Aggregate bin.
- Filler bin.
- Water and Emulsion Tanks.
- Additive Tanks.
- Aggregates and filler conveyors to supply the mixer box.
- Pump or compressed air system to supply the emulsion/water.
- Mixer Box.
- Spreader box to place the mixed slurry on the job.

3.20.4.4 Calibration of Machine:

Slurry seal laying machine shall be calibrated for flow of all the constituents as per the job mix in presence of Engineer. No machine shall be allowed to work on the project until the calibration has been completed and accepted by the Engineer. 2 kg samples of slurry seal mix will be taken and verified for proportioning and mix consistency. The verification for application rate shall also be carried out in Presence of the Engineer. The procedure for calibration and verification is as given in ASTM D 3910-: 2021.

3.20.4.5 Application of Slurry seal:

A calibrated slurry seal machine, as per requirements of job mix, shall be used to spread the material. The surface shall be pre- wetted by fogging ahead of the spreader box (if required under hot weather conditions). The rate of application shall be adjusted during

the day to suit temperature, surface texture and humidity. The mixture shall be agitated and mixed uniformly in the spreader box by means of twin shafted paddles or spiral augurs fixed in spreader box. A front seal shall be provided to ensure no loss of the mixture at the road contact point. The rear seal shall act as final strike off and shall be adjustable. The spreader box and rear strike off shall be so designed and operated that a uniform consistency is achieved to produce free flow of material to the rear strike off. A Secondary strike off shall have the same adjustment as the spreader box. The spreader box shall have the suitable means provided to side shift the box to compensate for variation in pavement geometry. Sufficient amount of material shall be carried in all parts of spreader box at all times so that a complete coverage is obtained. Overloading of the spreader box shall be avoided. No lumping, balling and unmixed aggregates shall be permitted. No streak, caused by oversized aggregates shall be left on the finished surface. Longitudinal joints shall correspond with the edges of existing traffic lanes. The other patterns of longitudinal joints may be permitted, if pattern will not adversely affect the quality of finished surface. In case streak is formed, it shall be corrected immediately by fresh material and with use of squeeze. Longitudinal joints, common to two traffic lanes shall be butt joints with overlap not to exceed an average of 60-100 mm the mixture shall be uniform and homogeneous after spreading on existing surfaces and shall not show separation of the emulsion and aggregates after setting.

3.20.4.6 Rate of Application:

As per Table 3.20-1 (by weight of dry aggregates)

3.20.4.7 Rolling:

Generally rolling is not required, where rolling is felt necessary due to inadequate cohesion, a pneumatic type roller having individual wheel load between 0.75 to 1.5 tone shall be used. Rolling shall commence as soon as the slurry has set.

3.20.5 Surface Finish Quality Control:

The surface finish of construction shall conform to the general requirements of surface evenness and surface roughness as per general clauses of the specification.

3.20.6 Opening to Traffic:

Surface shall be opened to traffic after slurry is in completely set condition. The maximum setting time shall be 4 hours. Speed of traffic shall be restricted to 20 km per hour for next 12 hours.

3.20.7 Arrangements for Traffic:

During the period of construction, arrangements for traffic shall be made as specified in the general provisions of the contract.

3.20.8 Measurement for Payment

Slurry seal shall be measured as finished work as specified, in square meters.

3.20.9 Payment

The contract unit rate for slurry seal shall be payment in full for carrying out the required operations including full compensation for all components of the work including arrangement of traffic, preparation of surface, providing all materials, mixing, transportation, laying and compaction of mix, all labor, tools, equipment and plat etc

Pay items shall be:

3/20/1	Slurry seal	square meters

3.21 BRICK PAVEMENT

3.22.1 Description

This work shall consist of furnishing and laying bricks on a prepared and accepted subgrade or improved subgrade to form brick pavement in accordance with these Specifications, and to the lines, levels, grades, dimensions and cross sections shown on the Drawings, or as directed by the Engineer.

3.21.2 Subgrade and Improved Subgrade

The subgrade or improved subgrade shall conform to the provisions of Sections 2.7.

3.21.3 Materials

The materials shall consist of first class bricks, which meet the requirements of Section 5.5.2, and sand, which meets the requirements of grading envelope E in Table 2.8-1 of Section 2.8.2.

3.21.4 Brick on End Edging

3.21.4.1 Description

This work consists of providing and placing brick on end edging along the road adjacent to the side of the pavement of single layer brick flat soling and herringbone bond brick.

3.21.4.2 Construction Methods.

Bricks shall be laid on end edging with their longest side vertical and shortest side perpendicular to the road including necessary excavation filling and ramming to the satisfaction of the Engineer. The completed work shall be true to line and level and grade as indicated on the Drawings. Interstices between brick edging and adjacent paving or soling shall be filled by brushing in sand until voids are filled; the edging shall then be sprinkled with water.

3.21.5 Single Layer Brick Flat Soling

3.21.5.1 Description.

This item consists of providing single layer brick flat soling on accepted subgrade or improved subgrade.

3.21.5.2 Construction Methods.

The bricks shall be laid flat on a 75 mm thick compacted sand cushion layer over the prepared subgrade or improved subgrade surface. Bricks shall be laid in a regular and uniform manner. Interstices of bricks shall be filled with sand, and water shall be applied by sprinkling. No bricks shall be laid on loose earth or earth filling which has not been compacted to the required density and no bricks shall be laid on any surface which has not been inspected and approved by the Engineer.

3.21.6 Brick on Edge Pavement in Herringbone Bond

3.21.6.1 Description

This work shall consist of a base composed of bricks, laid on edge in a herringbone pattern on a 12 mm sand cushion, placed on a prepared single layer brick flat soling in accordance with these Specifications and to the lines, grades, levels, dimensions and cross sections shown on the Drawings or as required by the Engineer.

3.21.6.2 Construction Methods

The bricks shall be laid on edge in a single layer in a herringbone pattern to the lines, grades, levels, dimensions and cross section shown on the Drawings or as required by the Engineer. The edge of the layer shall be made with cut bricks to produce a line, which is compatible with brick edging.

The joints shall be filled with sand brushed in and the completed layer shall be sprinkled liberally with water.

3.21.6.3 Surface Tolerance

In those areas in which pavement is to be placed, any deviation in excess of 10 mm from a straight edge 3 metres long applied to the surface parallel to the centreline of the road and 12 mm from a 3 metres straight edge laid transversely, shall be corrected by removal, reshaping and relaying.

3.21.7 Measurement

Brick on end edging shall be measured in linear metres of completed and accepted work. Brick flat soling and herringbone bond brick pavement shall be measured in square metres of completed and accepted work.

3.21.8 Payment

This work, measured as described above shall be paid for at the Contract unit rates detailed below. The rates shall include the supply of all required materials and all labour, equipment, tools and incidentals necessary to complete the works as specified.

Pay items shall be:

3/21/1	Brick on End Edging	Linear Metre
3/21/2	Single Layer Brick Flat Soling including 75 mm thick Compacted Sand Cushion	Square Metre
3/21/3	Herring Bone Brick Pavement including 12 mm Sand Cushion	Square Metre

3.22 LEAN CEMENT CONCRETE

3.22.1 Scope

The work shall consist of construction of dry lean concrete sub-base for cement concrete pavement in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross-sections shown on the drawings or as directed by the Engineer. The work shall include furnishing of all plant and equipment, materials and labour including all operations in connection with the work as approved by the Engineer.

3.22.2 Materials

The design parameters of dry lean concrete sub-base, viz., width, thickness, grade of concrete, details of joints, if any, etc. shall be as stipulated in the Contract drawings.

3.22.2.1 Cement:

Cement shall conform to the requirements of Section-5.1.2 of General Specifications.

3.22.2.2 Aggregates:

Aggregates shall conform to the requirements of Section-5.1.2 of General Specifications.

3.22.2.3 Water:

Water shall conform to the requirements of Section-5.1.2 of General Specifications.

3.22.3 Proportioning of Materials for the Mix

3.22.3.1

The mix shall be proportioned to comply with Section-5.1.2.3 and Section- 5.1.2.4 of General specifications. The water content shall be adjusted to the optimum as per Clause ~~3.14.3.2~~ for facilitating compaction by rolling. The strength and density requirements of concrete shall be determined in accordance with Clause ~~3.14.5~~ by making trial mixes.

3.22.3.2 Moisture content:

Moisture content shall conform to the requirements of Section-5.1.2.3 of General Specifications.

3.22.3.3 Cement content:

Cement content shall conform to the requirements of Section-5.1.2.3 of General Specifications.

3.22.3.4 Concrete strength:

Concrete strength shall conform to the requirements of Section-5.1.2.3 of General Specifications.

3.22.4 Construction

3.22.4.1 General:

The place and programme of the lean concrete sub-base construction shall be matching suitably with the programme of construction of the cement concrete pavement over it. The dry lean concrete sub-base shall be overlaid with cement concrete pavement only after 7 days of its construction.

3.22.4.2 Batching and mixing:

The batching plant shall be capable of proportioning the materials by weight, each type of material being weighed separately in accordance with Clause 3.23.9.3.2. The cement from the bulk stock shall be weighed separately. The capacity of batching and mixing plant shall be at least 25 per cent higher than the proposed capacity for the laying arrangements. The batching and mixing shall be carried out preferably in a forced action central batching and mixing plant having necessary automatic controls to ensure accurate proportioning and mixing. Other types of mixers shall be permitted subject to demonstration of their satisfactory performance during the trial length. The type and capacity of the plant shall be got approved by the Engineer before commencement of the trial length. The weighing balances shall be calibrated by weighing the aggregates, cement, water and admixtures physically either by weighing with large weighing machine or in a weigh bridge. The accuracy of weighing scales of the batching plant shall be within ± 2 per cent in the case of aggregates and ± 1 percent in the case of cement and water.

The design features of Batching Plant should be such that the shifting operations of the plant will not take very long time when they are to be shifted from place to place with the progress of the work.

3.22.4.3 Transporting:

Plant mix lean concrete shall be discharged immediately from the mixer, transported directly to the point where it is to be laid and protected from the weather by covering the tippers/dumpers with tarpaulin during transit. The concrete shall be transported by tipping trucks, sufficient in number to ensure a continuous supply of material to feed the laying equipment to work at a uniform speed and in an uninterrupted manner. The lead of the batching plant to paving site shall be such that the travel time available from mixing to paving as specified in Clause 3.22.4.5.2 will be adhered to.

3.22.4.4 Placing:

Lean concrete shall be laid/placed by a paver with electronic sensor or any other method approved by Engineer. The equipment shall be capable of laying the material in one layer in an even manner without segregation, so that after compaction the total thickness is as specified. The paving machine shall have high amplitude tamping bars to give good initial compaction to the sub-base.

The laying of the two-lane road sub-base may be done either in full width or lane by lane. Preferably the lean concrete shall be placed and compacted across the full width of the road, by constructing it in one go or in two lanes running forward simultaneously. Transverse and

longitudinal construction joints shall be staggered by 500-1000 mm and 200-400 mm respectively from the corresponding joints in the overlaying concrete slabs.

3.22.4.5 Compaction:

3.22.4.5.1 The compaction shall be carried out immediately after the material is laid within the initial setting time of cement and leveled. In order to ensure thorough compaction, which is essential, rolling shall be continued on the full width till there is no further visible movement under the roller and the surface is closed.

3.22.4.5.2 The spreading, compacting and finishing of the lean concrete shall be carried out as rapidly as possible and the operation shall be so arranged as to ensure that the time between the mixing of the first batch of concrete in any transverse section of the layer and the final finishing of the same shall not exceed 90 minutes when the concrete temperature is above 25 and below 30 degree Celsius and 120 minutes if less than 25 degree Celsius. This period may be reviewed by the Engineer in the light of the results of the trial run but in no case shall it exceed 2 hours. Work shall not proceed when the temperature of the concrete exceeds 30 degree Celsius. If necessary, chilled water or addition of ice may be resorted to for bringing down the temperature. It is desirable to stop concreting when the ambient temperature is above 35°C. After compaction has been completed, roller shall not stand on the compacted surface for the duration of the curing period except during commencement of next day's work near the location where work was terminated the previous day.

3.22.4.5.3 Double drum smooth-wheeled vibratory rollers of minimum 80 to 100 kN static weight are considered to be suitable for rolling dry lean concrete. In case any other roller is proposed, the same shall be got approved from the Engineer, after demonstrating its performance. The number of passes required to obtain maximum compaction depends on the thickness of the lean concrete, the compatibility of the mix, and the weight and type of the roller etc., and the same as well as the total requirement of rollers for the job shall be determined during trial run by measuring the in-situ density and the scale of the work to be undertaken.

3.22.4.5.4 The final lean concrete surface on completion of compaction and immediately before overlaying shall be well closed, free from movement under roller and free from ridges, low spots, cracks, loose material, pot holes, ruts or other defects. The final surface shall be inspected immediately on completion and all loose, segregated or defective areas shall be corrected by using fresh lean concrete and compacted as per Specification. For repairing honeycombed surface, concrete with aggregates of size 10 mm and below shall be spread and compacted. It is necessary to check the level of the rolled surface for compliance. Any level/thickness deficiency should be corrected after applying cement concrete with aggregates of size 10 mm and below after roughening the surface. Similarly the surface regularity also should be checked with 3m straight edge. The deficiency should be made up with concrete with aggregates of size 10 mm and below.

3.22.5 Trial Mixes:

Trial Mixes shall conform to the requirements of Section- 5.1.2.3 of General Specifications.

3.22.6 Curing:

Curing shall conform to the requirements of Section- 5.1.3.11 of General Specifications.

3.22.7 Removal of Scaffolding and Formwork:

Forms and scaffolding shall conform to the requirements of Section-5.1.3.12 of General Specifications.

3.22.8 Repair of Concrete:

Repair of Concrete shall conform to the requirements of Section-5.1.3.13 of General Specifications.

3.22.9 Traffic:

No heavy commercial vehicles like trucks and buses shall be permitted on the lean concrete sub-base after its construction. Light vehicles if unavoidable may, however, be allowed after 7 days of its construction with prior approval of the Engineer.

3.22.10 Tolerances for Surface Regularity, Level, Thickness and Strength:

The tolerances for surface regularity, level, thickness and strength shall conform to the requirements and Control of quality of materials and works shall be exercised satisfactory to the Engineer.

3.22.11 Measurements:

The unit of measurement for dry lean concrete pavement shall be the unit of volume in cubic metre of concrete placed, based on the net plan areas for the specified thickness shown on the drawings or as directed by the Engineer.

3.22.12 Payment

The Contract unit rate payable for dry lean concrete sub-base shall be payment in full for carrying out the required operations including full compensation for all labour, materials and equipment, mixing, transport, placing, compacting, finishing, curing, testing and incidentals to complete the work as per Specifications, all royalties, fees, storage and rents where necessary and all leads and lifts.

Pay item shall be:

03/22/01	Lean Cement Concrete (as specified in Design)	Cubic metre

3.23 CEMENT CONCRETE PAVEMENT

3.23.1 Scope

3.23.1.1 The work shall consist of construction of cement concrete pavement in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross sections shown on the drawings. The work shall include furnishing of all plant and equipment, materials and labor and performing all operations in connection with the work, as approved by the Engineer.

3.23.1.2 The design parameters, viz., thickness of pavement slab, grade of concrete, joint details etc. shall be as stipulated in the contract drawings.

3.23.2 Materials

3.23.2.1 Cement:

Cement shall conform to the requirements of Section-5.1.2 of General Specifications.

3.23.2.2 Admixtures:

Admixtures shall conform to the requirements of Section-5.1.2 of General Specifications.

3.23.2.3 Aggregates:

Aggregates shall conform to the requirements of Section-5.1.2 of General Specifications. Aggregates for concrete shall be tested for determining the reactivity from accelerated mortar bar test (AASHTO T303) and concrete prism test (ASTM C 1293) if specified in the particular specification.

3.23.2.4 Water:

Water shall conform to the requirements of Section-5.1.2 of General Specifications.

3.23.2.5 Admixtures:

Admixtures shall conform to the requirements of Section-5.1.2 of General Specifications.

3.23.2.6 High Yield Deformed Steel Reinforcing Bars for dowels and tie bars:

Reinforcing bars for dowels and tie bars shall conform to the requirements of Section-5.2 of General Specifications.

3.23.2.7 Pre-moulded joint filler:

Joint filler board for expansion joints which are proposed for use only at some abutting structures like bridges and culverts shall be of 20-25 mm thickness within a tolerance of ± 1.5 mm and of a firm compressible material and complying with the requirements of BS Specification Clause No. 2630 or Specification for Highway Works, Vol. I Clause 1015. It shall be 25 mm less in depth than the thickness of the slab within a tolerance of ± 3 mm and provided to the full width between the side forms. It shall be in suitable lengths, which shall not be less than one lane width. Holes to accommodate dowel bars shall be accurately bored or punched out to give a sliding fit on the dowel bars.

3.23.2.8 Joint sealing compound:

The joint sealing compound shall be of hot poured, elastomeric type or cold polysulphide type having flexibility, resistance to age hardening -and durability. If the sealant is of hot poured type it shall conform to AASHTO M282 and cold applied sealant shall be in accordance with BS 5212 (Part 2).

3.23.2.9 Storage of materials:

Storage of materials shall conform to the requirements of Section-5.1.3.3 of General Specifications.

3.23.3 Proportioning of Concrete

3.23.3.1 After approval by the Engineer of all the materials to be used in the concrete, the Contractor shall submit the mix design based on weighed proportions of all ingredients for the approval of the Engineer. The mix design shall be submitted at least 30 days prior to the paving of trial length and the design shall be based on laboratory trial mixes using the approved materials and methods as agreed to by the Engineer. The mix design shall be based on the flexural strength of concrete.

3.23.3.2 Cement content:

Cement content shall conform to the requirements of Section-5.1.2.3 of General Specifications.

3.23.3.3 Concrete strength:

Concrete strength shall conform to the requirements of Section-5.1.2.3 of General Specifications.

3.23.3.4 Workability

3.23.3.4.1 Workability at pouring site.

The workability of the concrete at the point of placing shall be adequate for the concrete to be fully compacted and finished without undue flow. The optimum workability for the mix to suit the paving plant being used shall be determined by the Contractor and approved by the Engineer. The control of workability in the field shall be exercised by the slump test as per STP-9.1. Usually, no slump concrete should be used for pavement works.

3.23.3.4.2 Workability at Batching Plant.

The workability requirement at the Batching Plant and paving site shall be established by slump tests carried during trial paving. These requirements shall be established from season to season and also when the lead from Batching plant site to the paving site changes. The workability shall be established for the type of paving equipment available. A slump value in the range of 30 ± 15 mm is reasonable for paving works but this may be modified depending upon the site requirement and got approved by the Engineer. These tests shall be carried out on every truck/dumper at Plant site and paving site initially when the work commences but subsequently the frequency can be reduced to alternate trucks or as per the instructions of the Engineer.

3.23.3.5 Design mix

3.23.3.5.1 The Contractor shall carry out laboratory trials according to the ACI (American Concrete Institute) method of concrete mix design with the materials from the approved sources to be used. Trial mixes shall be made in presence of the Engineer or his representative and the design mix shall be subject to the approval of the Engineer. They shall be repeated if necessary, until the proportions that will produce a concrete, which compiles in all respects with this Specification, and conforms to the requirement of the design/drawings have been determined.

3.23.3.5.2 The proportions determined as a result of the laboratory trial mixes may be adjusted if necessary, during the construction of the trial length. Thereafter, neither the materials nor the mix proportions shall be varied in any way except with the written approval of the Engineer.

3.23.3.5.3 The Contractor shall submit results of material tests on the proposed materials to the Engineer for his approval at least seven days in advance of its use. Fresh approval shall be required when the material is changed or as per order of the Engineer.

3.23.4 Separation Membrane

A separation membrane shall be used between the concrete slab and the lean Concrete sub-base. Separation membrane shall be impermeable plastic sheeting 125 microns thick laid flat without creases. Before placing the separation membrane, the sub-base shall be swept clean of all the extraneous materials using air compressor. Wherever overlap of plastic sheets is necessary, the same shall be at least 300 mm and any damaged sheeting shall be replaced at the Contractor's expense. The separation membrane may be nailed to the lower layer with concrete nails.

3.23.5 Joints

3.23.5.1 The location and type of joints shall be as shown in the drawing. Joints shall be constructed depending upon their functional requirement as detailed in the following paragraphs. The location of the joints should be transferred accurately at the site and mechanical saw cutting of joints done as per stipulated dimensions. It should be ensured that the full required depth of cut is made from edge to edge of the pavement. Transverse and longitudinal joints in the pavement and sub-base shall be staggered so that they are not coincident vertically and are at least 1m and 0.3m apart respectively. Sawing of joints shall be carried out with diamond studded blades soon after the concrete has hardened to take the load of the sawing machine and personnel without damaging the texture of the pavement. Sawing operation could start as early as 6-8 hours depending upon the season.

3.23.5.2 Transverse joints

3.23.5.2.1 Transverse joints shall be contraction and expansion joints constructed at the spacing described in the Drawings. Transverse joints shall be straight within the following tolerances along the intended line of joints which is the straight-line transverse to the

longitudinal axis of the carriageway at the position proposed by the Contractor and agreed to by the Engineer, except at road junctions or roundabouts where the position shall be as described in the drawings:

Deviations of the filler board in the case of expansion joints from the intended line of the joint shall not be greater than ± 10 mm. The best-fit straight line through the joint grooves as constructed shall be not more than 25 mm from the intended line of the joint.

Deviations of the joint groove from the best-fit straight line of the joint shall not be greater than 10 mm.

Transverse joints on each side of the longitudinal joint shall be in line with each other and of the same type and width. Transverse joints shall have a sealing groove, which shall be sealed in compliance with Clause 3.23.10.3

3.23.5.2.2 Contraction joints:

Contraction joints shall consist of a mechanical sawn joint groove, 3 to 5 mm wide and 1/4 to 1/3 depth of the slab ± 5 mm or as stipulated in the drawings and dowel bars complying with Clause 3.23.6.5 and as detailed in the drawings. The contraction joints shall be cut as soon as the concrete has undergone initial hardening and is hard enough to take the load of joint sawing machine without causing damage to the slab

3.23.5.2.3 Expansion joints:

The expansion joints shall consist of a joint filler board complying with Clause 3.23.2.7 and dowel bars complying with Clause 3.23.6 and as detailed in the drawings. The filler board shall be positioned vertically with the prefabricated joint assemblies along the line of the joint within the tolerances given in Clause 3.23.6.2.1 and at such depth below the surface as will not impede the passage of the finishing straight edges or oscillating beams of the paving machines. The adjacent slabs shall be completely separated from each other by providing joint filler board. Space around the dowel bars, between the sub-base and the filler board shall be packed with a suitable compressible material to block the flow of cement slurry.

3.23.5.3 Transverse construction joint:

Transverse construction joints shall be placed whenever concreting is completed after a day's work or is suspended for more than 30 minutes. These joints shall be provided at the regular location of contraction joints using dowel bars. The joint shall be made butt type. At all construction joints, steel bulkheads shall be used to retain the concrete while the surface is finished. The surface of the concrete laid subsequently shall conform to the grade and cross sections of the previously laid pavement. When positioning of bulk head/ stop-end is not possible, concreting to an additional 1 or 2 m length may be carried out to enable the movement of joint cutting machine so that joint grooves may be formed and the extra 1 or 2 m length is cut out and removed subsequently after concrete has hardened.

3.23.5.4 Longitudinal joint

3.23.5.4.1 The longitudinal joints shall be saw cut as per details of the joints shown in the drawing. The groove may be cut after the final set of the concrete. Joints should be sawn to at least 1/3 the depth of the slab ± 5 mm as indicated in the drawing.

3.23.5.4.2 Tie bars shall be provided at the longitudinal joints as per dimensions and spacing shown in the drawing and in accordance with Clause 3.23.2.6.

3.23.6 Dowel bars

3.23.6.1 Dowel bars shall be mild steel rounds in accordance with Clause 3.23.2.6 with details/dimensions as indicated in the drawing and free from oil, dirt, loose rust or scale. They shall be straight, free of irregularities and burring restricting slippage in the concrete. The sliding ends shall be sawn or cropped cleanly with no protrusions outside the normal diameter of the bar. The dowel bar shall be supported on cradles/dowel chairs in pre-fabricated joint assemblies positioned prior to the construction of the slabs or mechanically inserted with vibration into the plastic concrete by a method which ensures correct placement of the bars besides full re-compaction of the concrete around the dowel bars.

3.23.6.2 Unless shown otherwise on the drawings, dowel bars shall be positioned at mid depth of the slab within a tolerance of ± 20 mm, and centered equally about intended lines of the joint within a tolerance of ± 25 mm. They shall be aligned parallel to the finished surface of the slab and to the center line of the carriageway and to each other within tolerances given hereunder, the compliance of which shall be checked as per Clause 3.15.10.7.

i) For bars supported on cradles prior to the laying of the slab:

All bars in a joint shall be within ± 3 mm per 300 mm length of bar

2/3rd of the bars shall be within ± 2 mm per 300 mm length of bar

No bar shall differ in alignment from an adjoining bar by more than 3 mm per 300 mm length of bar in either the horizontal or vertical plane

Cradles supporting dowel bar shall not extend across the line of joint i.e. no steel bar of the cradle assembly shall be continuous across the joint

ii) For all bars inserted after laying of the slab:

Twice the tolerance for alignment as indicated in (i) above

3.23.6.3 Dowel bars, supported on cradles in assemblies, when subject to a load of 110 N applied at either end and in either the vertical or horizontal direction (upwards and downwards and both directions horizontally) shall conform to be within the following limits:

Two-thirds of the number of bars of any assembly tested shall not deflect more than 2 mm per 300 mm length of bar

The remainder of the bars in that assembly shall not deflect more than 3 mm per 300 mm length of bar.

3.23.6.4 The assembly of dowel bars and supporting cradles, including the joint filler board in the case of expansion joints, shall have the following degree of rigidity when fixed in position:

For expansion joints, the deflection of the top edge of the filler board shall be not greater than 13 mm, when a load of 1.3 kN is applied perpendicular to the vertical face of the joint filler board and distributed over a length of 600 mm by means of a bar or timber packing, at mid depth and midway between individual fixings, or 300 mm from either end of any length of filler board, if a continuous fixing is used. The residual deflection after removal of the load shall be not more than 3 mm.

The joint assembly fixings to sub-base shall not fail under the 1.3kN load applied for testing the rigidity of the assembly but shall fail before the load reaches 2.6 kN.

The fixings for contraction joint shall not fail under 1.3 kN load and shall fail before the load reaches 2.6 kN when applied over a length of 600 mm by means of a bar or timber packing placed as near to the level of the line of fixings as practicable.

Fixings shall be failed when there is displacement of the assemblies by more than 3 mm with any form of fixing, under the test load. The displacement shall be measured at the nearest part of the assembly to the centre of the bar or timber packing.

3.23.6.5 Dowel bars shall be covered by a thin plastic sheath for at least two-thirds of the length from one end for dowel bars in contraction joints or half the length plus 50 mm for expansion joints. The sheath shall be tough, durable and of an average thickness not greater than 1.25 mm. The sheathed bar shall comply with the following pull-out tests:

Four bars shall be taken at random from stock and without any special preparation shall be covered by sheaths as required in this Clause. The ends of the dowel bars which have been sheathed shall be cast centrally into concrete specimens 150 x 150 x 600 mm, made of the same mix proportions to be used in the pavement, but with a maximum nominal aggregate size of 20 mm and cured in accordance with IS: 516. At 7 days a tensile load shall be applied to achieve a movement of the bar of at least 0.25 mm. The average bond stress to achieve this movement shall not be greater than 0.14 MPa.

3.23.6.6 For expansion joints, a closely fitting cap 100 mm long consisting of waterproofed cardboard or an approved synthetic material like PVC or GI pipe shall be placed over the sheathed end of each dowel bar. An expansion space at least equal in length to the thickness of the joint filler board shall be formed between the end of the cap and the end of the dowel bar by using compressible sponge. To block the entry of cement slurry between dowel and cap it may be taped.

3.23.6.7 Tie bars

3.23.6.7.1 Tie bars in longitudinal joints shall be deformed steel bars of strength in accordance with Clause 3.23.2.6. The bars shall be free from oil, dirt, loose rust and scale.

3.23.6.7.2 Tie bars projecting across the longitudinal joint shall be protected from corrosion for 75mm on each side of the joint by a protective coating of bituminous paint with the approval of the Engineer. The coating shall be dry when the tie bars are used.

3.23.6.7.3 Tie bars in longitudinal joints shall be made up into rigid assemblies with adequate supports and fixings to remain firmly in position during the construction of the slab. Alternatively, tie bars at longitudinal joints may be mechanically or manually inserted into the plastic concrete from above by vibration using a method, which ensures correct placement of the bars and re-compaction of the concrete around the tie bars.

3.23.6.7.4 Tie bars shall be positioned to remain within the middle third of the slab depth as indicated in the drawings and approximately parallel to the surface and approximately perpendicular to the line of the joint, with the centre of each bar on the intended line of the joints within a tolerance of $\pm 50\text{mm}$, and, with a minimum cover of 30 mm below the joint groove.

3.23.7 Weather and Seasonal Limitations

3.23.7.1 Concreting during monsoon months:

When concrete is being placed during monsoon months and when it may be expected to rain, sufficient supply of tarpaulin or other water proof cloth shall be provided along the line of the work. Any time when it rains, all freshly laid concrete which had not been covered for curing purposes shall be adequately protected. Any concrete damaged by rain shall be removed and replaced. If the damage is limited to texture, it shall be retextured in accordance with the directives of the Engineer.

3.23.7.2 Concreting in hot weather:

No concreting shall be done when the concrete temperature is above 30 degree Centigrade. Besides, in adverse conditions like high temperature, low relative humidity, excessive wind velocity, imminence of rains etc., if so desired by the Engineer, tents on mobile trusses may be provided over the freshly laid concrete for a minimum period of 3 hours as directed by the Engineer. The temperature of the concrete mix on reaching the paving site shall not be more than 30° C. To bring down the temperature, if necessary, chilled water or ice flakes should be made use of.

No concreting shall be done when the concrete temperature is below 5 degree Centigrade and the temperature is descending.

3.23.8 Side Forms, Rails

3.23.8.1 Side forms and rails:

All side forms shall be of mild steel of depth equal to the thickness of pavement or slightly less to accommodate the surface irregularity of the sub-base. The forms can be placed on series of steel packing plates or shims to take care of irregularity of sub-base. They shall be

sufficiently robust and rigid to support the weight and pressure caused by paving equipment. Side forms for use with wheeled paving machines shall incorporate metal rails firmly fixed at a constant height below the top of the forms. The forms and rails shall be firmly secured in position by not less than 3 stakes/pins per each 3 m length so as to prevent movement in any direction. Forms and rails shall be straight within a tolerance of 3 mm in 3 m and when in place shall not settle in excess of 1.5 mm in 3 m while paving is being done. Forms shall be cleaned and oiled immediately before each use. The forms shall be bedded on a continuous bed of low moisture content lean cement mortar or concrete and set to the line and levels shown on the drawings within tolerances ± 10 mm and ± 3 mm respectively. The bedding shall not extend under the slab and there shall be no vertical step between adjacent forms of more than 3 mm. The forms shall be got inspected from the Engineer for his approval before 12 hours on the day before the construction of the slab and shall not be removed until at least 12 hours afterwards.

3.23.8.2 At all times sufficient forms shall be used and set to the required alignment for at least 200 m length of pavement immediately in advance of the paving operations, or the anticipated length of pavement to be laid within the next 24 hrs whichever is more.

3.23.9 Construction

3.23.9.1 General:

A systems approach may be adopted for construction of the pavement, and the Method Statement for carrying out the work, detailing all the activities including indication of line-cycle, equipment, personnel etc., shall be got approved from the Engineer before the commencement of the work. The above shall include the type, capacity and make of the batching and mixing plant besides the hauling arrangement and paving equipment. The capacity of paving equipment, batching plant as well as all the ancillary equipment shall be adequate for a paving rate of at least 300 m in one day.

3.23.9.2 Batching and mixing:

Batching and mixing of the concrete shall be done at a central batching and mixing plant with automatic controls, located at a suitable place which takes into account sufficient space for stockpiling of cement, aggregates and stationary water tanks. This shall be, however, situated at an approved distance, duly considering the properties of the mix and the transporting arrangements available with the Contractor.

3.23.9.3 Equipment for proportioning of materials and paving

3.23.9.3.1 Proportioning of materials shall be done in the batching plant by weight, each type of material being weighed separately. The cement from the bulk stock may be weighed separately from the aggregates and water shall be measured by volume. Wherever properly graded aggregate of uniform quality cannot be maintained as envisaged in the mix design, the grading of aggregates shall be controlled by appropriate blending

techniques. The capacity of batching and mixing plant shall be at least 25 per cent higher than the proposed capacity of the laying/paving equipment.

3.23.9.3.2 Batching plant and equipment:

General- The batching plant shall include minimum four bins, weighing hoppers, and scales for the fine aggregate and for each size of coarse aggregate. If cement is used in bulk, a separate scale for cement shall be included. The weighing hoppers shall be properly sealed and vented to preclude dust during operation. Approved safety devices shall be provided and maintained for the protection of all personnel engaged in plant operation, inspection and testing. The batch plant shall be equipped with a suitable non-resettable batch counter, which will correctly indicate the number of batches proportioned.

Bins and hoppers- Bins with minimum number of four adequate separate compartments shall be provided in the batching plant.

Automatic weighing devices-Batching plant shall be equipped to proportion aggregates and bulk cement by means of automatic weighing devices using load cells. The batching plant shall be calibrated as and when directed by the engineer.

Mixers- Mixers shall be pan type, reversible type or any other mixer capable of combining the aggregates, cement, and water into a thoroughly mixed and uniform mass within the specific mixing period, and of discharging the mixture, without segregation. Each stationary mixer shall be equipped with an approved timing device which will automatically lock the discharge lever when the drum has been charged and release it at the end of the mixing period. The device shall be equipped with a bell or other suitable warning device adjusted to give a clearly audible signal each time the lock is released. In case of failure of the timing device, the mixer may be used for the balance of the day while it is being repaired, provided that each batch is mixed 90 seconds or as per the manufacturer's recommendation. The mixer shall be equipped with a suitable non-resettable batch counter, which shall correctly indicate the number of batches mixed.

The mixers shall be cleaned at suitable intervals. The pickup and throw-over blades in the drum or drums shall be repaired or replaced when they are worn down 20 mm or more. The Contractor shall (1) have available at the job site a copy of the manufacturer's design, showing dimensions and arrangements of blades in reference to original height and depth, or (2) provide permanent marks on blade to show points of 20 mm wear from new conditions. Drilled holes of 5 mm diameter near each end and at midpoint of each blade are recommended. Batching Plant shall be calibrated in the beginning and thereafter at suitable interval not exceeding 1 month.

Control cabin- An air-conditioned centralised control cabin shall be provided for automatic operation of the equipment.

3.23.9.3.3 Paving equipment and concrete Saw:

Unless otherwise stated in the particular specifications, the concrete shall be placed with an approved fixed form or slip form paver with independent units designed to (i) spread, (ii) consolidate, screed and float-finish, (iii) texture and cure the freshly placed concrete in one complete pass of the machine in such a manner that a minimum of hand finishing will be necessary and so as to provide a dense and homogeneous pavement in

conformity with the plans and Specifications. The paver shall be equipped with electronic controls to control/sensor line and grade from either or both sides of the machine.

Vibrators shall operate at a frequency of 8300 to 9600 impulses per minute under load at a maximum spacing of 60 cm. The variable vibration setting shall be provided in the machine.

Concrete Saw -The Contractor shall provide adequate number of concrete saws with sufficient number of diamond-edge saw blades. The saw machine shall be either electric or petrol/diesel driven type. A water tank with flexible hose and pump shall be made available for this activity on priority basis. The Contractor shall have at least one standby saw in good working condition. The concreting work shall not commence if the saws are not in working condition.

3.23.9.4 Hauling and placing of concrete

3.23.9.4.1 Freshly mixed concrete from the central batching and mixing plant shall be transported to the paver site by means of trucks/tippers of sufficient capacity and approved design in sufficient numbers to ensure a constant supply of concrete. Covers shall be used for protection of concrete against the weather. The trucks/tippers shall be capable of maintaining the mixed concrete in a homogeneous state and discharging the same without segregation and loss of cement slurry. The feeding to the paver is to be regulated in such a way that the paving is done in an uninterrupted manner with a uniform speed throughout the day's work.

3.23.9.4.2 Placing of concrete

Concrete mixed in central mixing plant shall be transported to the site without delay and the concrete which, in the opinion of the Engineer, has been mixed too long before laying will be rejected and shall be removed from the site. The total time taken from the addition of the water to the mix, until the completion of the surface finishing and texturing shall not exceed 120 minutes when concrete temperature is less than 25°C and 90 minutes when the concrete temperature is between 25°C to 30°C. Trucks/tippers delivering concrete shall not run on plastic sheeting nor shall they run on completed slabs until after 28 days of placing the concrete. The Paver shall be capable of paving the carriageway as shown in the drawings, in a single pass and lift.

3.23.9.4.3 Where fixed form pavers are to be used, forms shall be fixed in advance as per Clause 3.23.8. of the Specifications. Before any paving is done, the site shall be shown to the Engineer, in order to verify the arrangement for paving besides placing of dowels, tie-bars etc., as per the relevant Clauses of this Specification. The mixing and placing of concrete shall progress only at such a rate as to permit proper finishing, protecting and curing of the pavement.

3.23.9.4.4 In all cases, the temperature of the concrete shall be measured at the point of discharge from the delivery vehicle.

3.23.9.4.5 The addition of water to the surface of the concrete to facilitate the finishing operations will not be permitted except with the approval of the Engineer when it shall be applied as a mist by means of approved equipment.

3.23.9.4.6 If considered necessary by the Engineer, the paving machines shall be provided with approved covers to protect the surface of the slab under construction from direct sunlight and rain or hot wind.

3.23.9.4.7 While the concrete is still plastic, its surface shall be brush textured in compliance with Clause 3.23.9.8 and the surface and edges of the slab cured by the application of a sprayed liquid curing membrane in compliance with Clause 3.23.10.3.7 After the surface texturing, but before the curing compound is applied, the concrete slab shall be marked with the chainage at every 100 m interval.

3.23.9.4.8 As soon as the side forms are removed, edges of the slabs shall be corrected wherever irregularities have occurred by using fine concrete composed of one part of cement to 3 parts of fine chips and fine aggregate under the supervision of the Engineer.

3.23.9.4.9 If the requirement for surface regularity fails to be achieved on two consecutive working days, then normal working shall cease until the cause of the excessive irregularity has been identified and remedied.

3.23.9.5 Construction by fixed form paver

3.23.9.5.1 The fixed form paving train shall consist of separate powered machines which spread, compact and finish the concrete in a continuous operation.

3.23.9.5.2 The concrete shall be discharged without segregation into a hopper spreader which is equipped with means for controlling its rate of deposition on to the sub-base. The spreader shall be operated to strike off concrete upto a level requiring a small amount of cutting down by the distributor of the spreader. The distributor of spreader shall strike off the concrete to the surcharge adequate to ensure that the vibratory compactor thoroughly compacts the layer. If necessary, poker vibrators shall be used adjacent to the side forms and edges of the previously constructed slab. The vibratory compactor shall be set to strike off the surface slightly high so that it is cut down to the required level by the oscillating beam. The machine shall be capable of being rapidly adjusted for changes in average and differential surcharge necessitated by changes in slab thickness or cross fall- The final finisher shall be able to finish the surface to the required

level and smoothness as specified, care being taken to avoid bringing up of excessive mortar to the surface by overworking.

3.23.9.6 Construction by slip form paver

3.23.9.6.1 The slip form paving train shall consist of power machine which spreads, compacts and finishes the concrete in a continuous operation. The slip form-paving machine shall compact the concrete by internal vibration and shape it between the side forms with either a conforming plate or by vibrating and oscillating finishing beams. The concrete shall be deposited without segregation in front of slip form paver across the whole width and to a height, which at all times is in excess of the required surcharge. The deposited concrete shall be struck off to the necessary average and differential surcharge by means of the strike off plate or a screw auger device extending across the whole width of the slab. The equipment for striking-off the concrete shall be capable of being rapidly adjusted for changes of the average and differential surcharge necessitated by change in slab thickness or cross fall.

3.23.9.6.2 The level of the conforming plate and finishing beams shall be controlled automatically from the guide wires installed as per Clause 3.23.8 by sensors attached at the four corners of the slip form paving machine. The alignment of the paver shall be controlled automatically from the guide wire by at least one set of sensors attached to the paver. The alignment and level of ancillary machines for finishing, texturing and curing of the concrete shall be automatically controlled relative to the guide wire or to the surface and edge of the slab.

3.23.9.6.3 Slip-form paving machines shall have vibrators of variable output, with a maximum energy output of not less than 2.5 KW per metre width of slab per 300 mm depth of slab for a laying speed upto 1.5 m per minute or pro-rata for higher speeds. The machines shall be of sufficient mass to provide adequate reaction during spreading and paving operations on the traction units to maintain forward movements during the placing of concrete in all situations.

3.23.9.6.4 If the edges of the slip formed slab slump to the extent that the surface of the top edge of the slab does not comply with the requirements of Clause 3.23.14, then special measures approved by the Engineer shall be taken to support the edges to the required levels and work shall be stopped until such time as the Contractor can demonstrate his ability to slip form the edges to the required levels.

3.23.9.6.5 Slip-form pavers with adequate width to pave the entire carriageway width in one go shall be employed unless specified in the Contract. In situations where full-width paving is not possible, paving in part widths may be permitted by the Engineer. Paving in part will be avoided, except in unavoidable circumstances. In case of part width paving, care shall be taken to ensure that while laying the next lane, bond between the remaining half length of tie bar or subsequently inserted tie bars and the newly laid concrete is adequately developed. Care shall be taken to avoid damage to the previous lane.

3.23.9.6.6 In case paving in separate lanes is allowed, work on the adjacent lane shall be permitted when the previously paved lane is cured for at least 14 days and is in a position; to bear the weight of paving machine. When the wheels or crawler tracks are to ply on the already paved surface, necessary precautions shall be taken by placing protective pads of rubber or similar material so that texture is not damaged. The wheel or track shall be reasonably away from the edge to avoid damage to the previously laid slab.

3.23.9.6.7 Tube floating upon the instructions of the Engineer, Contractor shall scrape the concrete surface when in plastic state with a 3 m long tube float fixed with a long and stable handle before texturing. Tube float shall be of an alloy steel tube of 50 to 60 mm diameter with a long and stable handle. The length of tube float shall preferably be longer than half the length of slab i.e., half the distance between two transverse contractions joints. This operation shall be done to minimize surface irregularity caused due to varied causes like frequent stoppages of work, surface deformation due to plastic flow etc. The tube float shall be placed at the center of the slab parallel to longitudinal joint and pulled slowly and uniformly towards the edges. After the use of float tube, it shall be frequently cleaned before further use. The slurry removed shall be discarded. This activity shall be advanced laterally by providing an overlap of half the length of tube float. The removal of the cement slurry from the surface shall be sufficient enough such that the texture is formed on a firm surface and is more durable. This operation, however, shall be carried out after removing bleeding water.

3.23.9.7 Construction by hand-guided method:

Areas in which hand-guided methods of construction become indispensable shall be got approved by the Engineer in writing in advance. Such work may be permitted only in restricted areas in small lengths. Work shall be carried out by skilled personnel as per methods, approved by the Engineer. The acceptance criteria regarding level, thickness, surface regularity, texture, finish, strength of concrete and all other quality control measures shall be the same as in the case of machine laid work.

3.23.9.8 Surface texture

After the final regulation of the slab and before the application of the curing membrane, the surface of concrete slab shall be brush-textured in a direction at right angles to the longitudinal axis of the carriageway.

The brushed surface texture shall be applied evenly across the slab in one direction by the use of a wire brush not less than 450 mm wide but longer brushes are preferred. The brush shall be made of 32-gauge tape wires grouped together in tufts spaced at 10 mm centres. The tufts shall contain an average of 14 wires and initially be 100 mm long. The brush shall have two rows of tufts. The rows shall be 20 mm apart and the tufts in one row shall be opposite the centre of the gap between tufts in the other row. The brush shall be replaced when the shortest tuft wears down to 90 mm long.

The texture depth shall be determined by the Sand Patch Test as described in Clause 3.23.14 This test shall be performed at least once for each day's paving and wherever the Engineer considers it necessary at times after construction as under: Five individual measurements of the texture depth shall be taken at least 2 m apart anywhere along a diagonal line across a lane width between points 50 m apart along the pavement. No

measurement shall be taken within 300 mm of the longitudinal edges of a concrete slab constructed in one pass.

Texture depths shall not be less than the minimum required when measurements are taken as given in Table 3.23-1 nor greater than a maximum average of 1.25 mm.

Table 3.23.-1

Time of Test		Number of Measurements	Required Texture Depth (mm)	
			Specified Value	Tolerance
1.	Between 24 hours and 7 days after the constn., of the slab or until the slab is first used by vehicles	An average of 5 measurements	1.00	± 0.25
2.	Not later than 6 weeks before the road is opened to public traffic.	An average of 5 measurements	1.00	+ 0.25 - 0.35

After the application of the brushed texture, the surface of the slab shall have a uniform appearance.

Where the texture depth requirements are found to be deficient, the Contractor shall make good the texture across the full lane width over length directed by the Engineer, by retexturing the hardened concrete surface in an approved manner.

3.23.10 Preparation and Sealing of Joint Grooves

3.23.10.1 General

All transverse joints in surface slabs shall be sealed using sealants described in Clause 3.14.2.8. Joints shall not be sealed before 14 days after construction.

3.23.10.2 Preparation of joint grooves for sealing

Joint grooves usually are not constructed to provide the minimum width specified in the drawings when saw cut joints are adopted. They shall be widened subsequently by sawing before sealing. Depth/width gauges shall be used to control the dimension of the groove.

If rough arises develop when grooves are made, they shall be ground to provide a chamfer approximately 5 mm wide. If the groove is at an angle upto 10 degree from the perpendicular to the surface, the overhanging edge of the sealing groove shall be sawn or ground perpendicular. If spalling occurs or the angle of the former is greater than 10 degrees, the joint sealing groove shall be sawn wider and perpendicular to the surface to encompass the defects upto a maximum width, including any chamfer, of 35 mm for transverse joints and 20 mm for longitudinal joints. If the spalling cannot be so eliminated then the arises shall be repaired by an approved thin bonded arris repair using cemeiititious materials

All grooves shall be cleaned of any dirt or loose material by air blasting with filtered, oil-free compressed air. If need arises the Engineer may instruct cleaning by pressurized water jets. Depending upon the requirement of the sealant manufacturer, the sides of the grooves may have to be sand blasted to increase the bondage between sealant and concrete.

The groove shall be cleaned and dried at the time of priming and sealing.

Before sealing the temporary seal provided for blocking the ingress of dirt, soil etc., shall be removed. A highly compressible heat-resistant paper-backed debonding strip as per drawing shall be inserted in the groove to serve the purpose of breaking the bond between sealant and the bottom of the groove and to plug the joint groove so that the sealant may not leak through the cracks. The width of debonding strip shall be more than the joint groove width so that it is held tightly in the groove. In the case of longitudinal joints, heat resistant tapes may be inserted to block the leakage through bottom of the joint.

3.23.10.3 Sealing with sealants

When sealants are applied, an appropriate primer shall also be used if recommended by the manufacturer and it shall be applied in accordance with their recommendation. The sealant shall be applied within the minimum and maximum drying times of the primer recommended by the manufacturer. Priming and sealing with applied sealants shall not be carried out when the naturally occurring temperature in the joint groove to be sealed is below 7° C.

If hot applied sealant is used it shall be heated and applied from a thermostatically controlled, indirectly heated preferably with oil jacketed melter and pourer having recirculating pump and extruder. For large road projects, sealant shall be applied with extruder having flexible hose and nozzle. The sealant shall not be heated to a temperature higher than the safe heating temperature and not for a period longer than the safe heating period, as specified by the manufacturer. The dispenser shall be cleaned out at the end of each day in accordance with the manufacturer's recommendations and reheated material shall not be used.

Cold applied sealants with chemical formulation like polysulphide may be used. These shall be mixed and applied within the time limit specified by the manufacturer. If primers are recommended they shall be applied neatly with an appropriate brush. The Movement Accommodation Factor (MAF) shall be more than 10 per cent.

The sealants applied at contraction phase of the slabs would result in bulging of the sealant over and above the slab. Therefore, the Contractor in consultation with the Engineer shall establish the right temperature and time for applying the sealant. Thermometer shall be hung on a pole in the site for facilitating control during the sealing operation.

Sealant shall be applied, slightly to a lower level than the slab with a tolerance of 5 ± 2 mm.

During sealing operation, it shall be seen that no air bubbles are introduced in the sealant either by vapours or by the sealing process.

3.23.11 Curing:

Curing shall conform to the requirements of Section- 5.1.3.11 of General Specifications.

3.23.12 Removal of Scaffolding and Formwork:

Forms and scaffolding shall conform to the requirements of Section-5.1.3.12 of General Specifications.

3.23.13 Repair of Concrete:

Repair of Concrete shall conform to the requirements of Section-5.1.3.12 of General Specifications.

3.23.14 Measurement of Texture Depth- Sand Patch Method

3.24.14.1 The following apparatus shall be used:

- o A cylindrical container of 25 ml internal capacity
- o A flat wooden disc 64 mm diameter with a hard rubber disc, 1.5 mm thick, stuck to one face, the reverse face being provided with a handle
- o Dry natural sand with a rounded panicle shape passing a 300 micron IS sieve and retained on a 150 micron IS sieve.

3.23.14.2 Method:

The surface to be measured shall be dried, any extraneous mortar and loose material removed and the surface swept clean using a wire brush both at right angles and parallel to the carriageway. The cylindrical container shall be filled with the sand, tapping the base 3 times on the surface to ensure compaction, and striking off the sand level with the top of the cylinder. The sand shall be poured into a heap on the surface to be treated. The sand shall be spread over the surface, working the disc with its face kept flat in a circular motion so that the sand is spread into a circular patch with the surface depressions filled with sand to the level of peaks.

3.23.14.3 The diameter of the patch shall be measured to the nearest 5 mm. The texture depth of concrete surface shall be calculated from $31000/(D \times D)$ mm where D is the diameter of the patch in mm.

3.23.15 Opening to Traffic

No vehicular traffic shall be allowed to run on the finished surface of a concrete pavement within a period of 28 days of its construction and until the joints are permanently sealed. The road may be opened to regular traffic after completion of the curing period of 28 days and after sealing of joints is completed including the construction of shoulder, with the written permission of the Engineer.

3.23.16 Tolerances for Surface Regularity, Level, Thickness and Strength

The tolerances for surface regularity, level, thickness and strength shall conform to the requirements and Control of quality of materials and works shall be exercised satisfactory to the Engineer.

3.23.17 Measurements for Payment

Cement Concrete pavement shall be measured as a finished work in square metres with specified thickness. The volume to be paid for will be calculated on the basis of thickness and plans shown on the project drawings and adjusted for the deficiency in thickness. No additional payment shall be made for extra thickness of the slab. The full payment will be made to this item after 28 days strength of the concrete is found to be satisfactory.

The unit for measurement for concrete pavement shall be the cubic metre of concrete placed, based on the net plan areas for the specified thickness shown on the Drawings or directed by the Engineer. The rate shall include all provisions of this Specification and shall include the provision of all materials including polythene film, concrete, stock piling, mixing, transport, placing, compacting, finishing, curing together with all formwork, and including testing and submission of test certificates and records. No deduction shall be made in measurement for openings provided that the area of each is less than 0.5 sq. m. The unit rate as entered in the Bill of Quantities shall also include the full costs of contraction, expansion, construction, and longitudinal joints. It shall also include joint filler, keys, caulking rod, debonding strip, sealant primer, joint sealant, dowel bar and tie rod.

3.23.17.1 Pavement thickness

All precautions and care shall be taken to construct pavement having uniform thickness as called for on the plans.

Thickness of the cement concrete pavement shall be calculated on the basis of level data of the cement concrete pavement and the underlying sub-base taken on a grid of 5 m x 3.5 m or 6.25 m x 3.5 m, the former measurement being in longitudinal direction.

A day's work is considered as a 'lot' for calculating the average thickness of the slab. In calculating the average thickness, individual measurements which are in excess of the specified thickness by more than 10 mm shall be considered as the specified thickness plus 10 mm.

Individual areas deficient by more than 25 mm shall be verified by the Engineer by ordering core cutting and if in his opinion the deficient areas warrant removal, they shall be removed and replaced with concrete of the thickness shown on the plans.

3.23.18 Payment

The Contract unit rate for the construction of the cement concrete shall be payment in full for carrying out the operations required for the different items of the work as per these Specifications including full compensation for all labour, tools, plant, equipments, testing and incidentals to complete the work as per Specifications, providing all materials to be incorporated in the work including all royalties, fees, storage, rents where necessary and all leads and lifts.

Pay items shall be:

03/24/01	Cement Concrete Pavement (Concrete class-30)	cu metre
03/24/02	Cement Concrete Pavement (Concrete Class - 35)	cu metre

3.24 STRESS ARRESTING MEMBRANE INTERLAYER (SAMI) ON CONCRETE BRIDGE DECKS

3.24.1. Description:

Concrete bridge decks are susceptible to various types of distresses, such as cracking, spalling, and corrosion, due to factors like traffic loads, temperature fluctuations, and exposure to environmental elements. To enhance the durability and prolong the service life of concrete bridge decks, engineers have developed innovative solutions, one of which is the Stress Arresting Membrane Interlayer (SAMI) system. The Stress Arresting Membrane Interlayer (SAMI) system offers several benefits for concrete bridge decks, including crack mitigation, waterproofing, enhanced durability, and improved ride quality. By following the appropriate application procedure, engineers can effectively incorporate SAMI into bridge deck rehabilitation and construction projects, enhancing the longevity and performance of these vital transportation assets.

3.24.2 Application Procedure of SAMI:

Surface Preparation:

The existing concrete bridge deck surface must be thoroughly cleaned and prepared before applying the SAMI system. This involves removing any loose debris, oil, grease, or other contaminants that may interfere with the bonding of the SAMI material.

SAMI Material Selection:

Various types of SAMI materials are available, but it is recommended to use polymer-modified (SBS) asphalt for bridges.

Application of SAMI: The SAMI material is typically applied using spray equipment. It is uniformly sprayed onto the prepared concrete deck surface to achieve the desired thickness, typically ranging from 3 to 6 millimeters. The application may require multiple passes to ensure complete coverage and uniformity.

Curing and Overlay Installation: After the SAMI material is applied, it needs to cure and achieve sufficient strength before the overlay is placed. The curing time can vary depending on the SAMI material and environmental conditions. Once cured, the asphalt is installed on top of the SAMI system. In some cases a firmly bonded membrane protected with asphalt overlay is used.

3.24.3 Quality Control:

Throughout the application process, quality control measures should be implemented to ensure proper thickness, uniform coverage, and adherence of the SAMI material. This may involve periodic testing, visual inspections, and verification of compliance with project specifications.

3.24.4 Payment

The Contract unit rate for this item shall be for the full compensation for all materials, labor, tools, plant, equipment, laying, testing and incidentals to complete the work as per Specifications.

Pay item shall be:

03/24/01 SAMI for Bridge Decks

Square Meter

Technical Specification (Particular)

General Specification Clause no.	Particular Specification
3.2.2	Type of Sub-base: Type I / Type II <i>(delete as appropriate)</i>
3.2.3.5	Light Weight Deflectometer (LWD) test shall be carried out/Not required <i>(delete as appropriate)</i> .
3.3.3.3	Mixing will be done by Plant/Manually <i>(delete as appropriate)</i> .
3.3.3.4	Laying of Base course shall be done by Paver/Motor Grader <i>(delete as appropriate)</i> .
3.3.3.5	Light Weight Deflectometer (LWD) test shall be carried out/Not required <i>(delete as appropriate)</i> .
3.4.2	a) The design CBR for lime-treated sub-base shall be not less than% <i>(put the appropriate value. It is generally 10%-15%)</i> b) The design UCS for lime-treated sub-base shall be not less than MPa <i>(put the appropriate value. It is generally 1.5-3.0 MPa)</i>
3.4.3.3	The pulverized equipment shall be disc harrows/rotavators <i>(delete as appropriate)</i> .
3.5.2	Quantity of cement to be used in stabilized mix percent <i>(mention as appropriate. Generally, 6 to 10 percent has to be used)</i>
3.5.4	a) Design UCS of cement-treated sub-base shall not be less than.....MPa <i>(put the appropriate value. It is generally 1.5-3.0 MPa)</i> b) Design UCS of cement-treated base shall not be less than.....MPa <i>(put the appropriate value. It is generally >5.0 MPa)</i>
3.8.3.5	Finished pavement surface shall be tested for IRI <i>(If not required, write "Not applicable")</i> .
3.13.1.2	a) Hamburg Wheel-Tracking test, AASHTO T324-19 shall be conducted. <i>(if not required, write "Not applicable")</i> b) Indirect Tensile Test, AASHTO T322-07 shall be conducted. <i>(if not required, write "Not applicable")</i> .
3.13.2.2	The bituminous material shall be of 40/50 or 60/70 penetration grade bitumen <i>(delete as appropriate)</i> .
3.14.2.2	The bituminous material shall be either PG70, PG76, PG 82 <i>(delete as appropriate)</i> .
3.23.2.3	Aggregate for concrete shall be tested/shall not be tested for determining the reactivity from Accelerated Mortar Bar Test (AASHTO T 303) and Concrete Prism Test (ASTM C1293). <i>(delete as appropriate)</i> .
3.23.9.3.3	The concrete shall be placed with an approved Fixed Form or Slip Form Paver/other approved method <i>(delete as appropriate)</i> .

SECTION 7 **GENERAL SPECIFICATIONS**

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DIVISION 4

FOUNDATION WORK

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4.1 BORED CAST IN PLACE PILES

4.1.1 Description

This work comprises the construction of bored cast in place piles for structures, including the provision of all material conforming to the requirements of these Specifications accordance details shown on the Drawings or other parts of the Contract Documents, or as directed by the Engineer.

Piles through water and soft soil layers shall be provided with a permanent steel casing if shown on the Drawings.

The pile boring shall be carried out using a temporary steel casing installed to sufficient depth so as to ensure that soil from sides of the hole do not drop into the concrete as it is placed. The temporary casing shall be withdrawn except when mud/sand flow condition exists.

The method of installation of piles, including details of the equipment shall be submitted by the contractor and got approved from the Engineer before commencement of work.

4.1.2 Materials

4.1.2.1 Steel Casing

This part of the Specifications only deals with the permanent steel casing. For steel casing used during boring of the pile see Section 4.1.3, Construction Methods.

When permanent steel casing is shown on the Drawings, the steel shall conform to the latest version of AASHTO Standard Specification M 183 (ASTM A36) or equivalent.

The metal casing shall be of sufficient thickness and strength to hold its original form and show no distortion while driving or when adjacent casings are driven.

The minimum thickness of the permanent steel casing shall be 10 mm. The thickness may be waived to 6(six) mm, if specified in Drawings. However, the contractor shall increase the casing thickness from the minimum specified thickness as necessary to satisfy the construction/installment requirement without any additional cost. The minimum length shall be from 100 mm above the bottom of the pile cap to 5 meter under the riverbed or into firm strata. If the surrounding soil or groundwater has a sulfate content equal to or greater than 0.2% (2,000 ppm) in soil or 300 ppm in groundwater, a permanent steel liner or steel casing shall be provided for the full depth of the pile through the aggressive strata. The effect of casing on pile capacity shall be checked. If the permanent casing is used in the boring operation or if the handling and transport require a greater thickness to avoid deformation or buckling, the increase in thickness shall be provided by the Contractor at his own expense.

The steel casing shall be furnished in appropriate lengths and the joints shall be leak-tight to minimize inflow of water as leakage of slurry during concreting and it should be approved by the Engineer.

The casing shall be handled and stored in a manner that shall prevent buckling and other deformation as well as accumulation of dirt, oil and paint. When placed in the work it shall be free from dirt, oil, grease, paint, mill scale and loose or thick rust.

The outside surface of the permanent casing of piles to river piers, for the depth indicated on the Drawings from the underside of the pile cap shall receive anticorrosion tar type paint. The paint shall be approved by the Engineer and its application shall follow the manufacturer's instructions.

For bored cast-in-situ piles, when casings are installed before boring, the borehole diameter shall not exceed the internal diameter of the casing. When casings are installed after boring, the borehole diameter shall not exceed the external diameter of the casing plus 50 mm, unless otherwise approved by the Engineer based on site-specific geotechnical conditions and design requirements.

4.1.2.2 Concrete

The concrete shall conform to Section 5.1 of these Specifications. Minimum Concrete class 25 with type 1 cement shall be used.

For coastal or saline environments, the type of cement to be used shall be determined as directed by the Engineer.

Concrete placed under water or drilling mud by tremie shall have a cement content of not less than 350 kg/m³.

The density and consistency of the concrete shall conform to the tremie casting method and the maintenance of sufficient workability (slump) of all the concrete during the casting and casing handling period, including reasonably calculated delays, shall be secured by a design mix, (including the necessary retarders and plasticizers), tested by trial mixes prior to the pile construction.

All relevant concrete properties such as slump, time of setting, temperature and strength shall be measured on the trial mixes.

4.1.2.3 Reinforcement

The reinforcement shall conform to Section 5.2 of these Specifications.

4.1.2.4 Drilling Fluid

The following clauses shall be complied with if bentonite mud is used to stabilize the boreholes:

A) Supply

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The Contractor shall obtain a certificate from the manufacturer of the bentonite powder, showing the properties of the consignment delivered to the site. This certificate shall be made available to the Engineer on request. The properties to be given by the manufacturer are the apparent viscosity range (in centipoises) and the gel strength range for solids in water.

Any other material proposed by the Contractor for the drilling fluid shall have to be approved by the Engineer.

B) Mixing

Bentonite and any other material shall be mixed thoroughly with clean water to make a suspension which shall maintain the stability of the pile excavation for the period necessary to place concrete and complete construction.

Where saline or chemically contaminated groundwater occurs, special precautions shall be taken to modify the bentonite in fresh water so as to render it suitable in all respects for the construction of piles.

C) Tests

The frequency of testing drilling fluid and the method and procedure of sampling shall be proposed by the Contractor and approved by the Engineer prior to the commencement of the work. The frequency may subsequently be varied as required depending on the consistency of the results obtained. The control tests shall cover the determination of density, viscosity, gel strength and pH values.

The Contractor shall supply all equipment and experienced operators required to carry out tests on the drilling mud. No additional payment shall be made for these tests which shall be considered as an essential part of the drilling operations.

D) Properties of bentonite

The bentonite suspension used for stabilizing boreholes shall conform to the following properties:

1. Density: 1.02–1.10 g/ml.
2. Marsh funnel viscosity: 30–40 seconds for 946 ml discharge.
3. pH: 9.5–11.5, measured using a pH meter or test paper.
4. Sand content: Less than 1% by volume, measured by sedimentation test.
5. Liquid limit: Not less than 400%.

The slurry shall be tested before concreting and after reuse, with properties maintained within specified limits unless otherwise approved by the Engineer based on site-specific requirements."

4.1.3 Construction Methods

4.1.3.1 General

The Contractor shall demonstrate to the satisfaction of the Engineer that his proposed construction methods for the piles do not result in the pile shafts being weakened by contamination of the concrete, by sectional reduction, by washing out of cement, by breaking during pulling of temporary casings or in any other way, including the construction of neighboring piles.

A) Assumed Procedure

The following construction procedure has been assumed in the design. The final construction procedure shall be as approved by the Engineer prior to commencing piling operations.

- 1.**Place permanent steel casing, if required, in position and embed casing toe into river bed or firm strata. If no permanent steel casing is specified a sufficient length of temporary steel casing shall be used to stabilize the upper part of the borehole.
- 2.**Bore and excavate inside the steel casing down to casing toe level, or to a level approved, and continue excavation to final pile tip level using either temporary casing under water, or using drilling mud. The fluid level (water or slurry) inside the borehole shall be maintained at least 2 metres above the external groundwater level or any artesian pressure level throughout boring and until concreting is completed using a tremie pipe, to ensure borehole stability and prevent collapse of the penetrated strata.
- 3.**Prior to the placing of reinforcement cage and concreting, the pile shaft shall be carefully clean up all mud or sedimentation from the bottom of borehole. The inadequate cleaning of the base case will lead to formation of soft base which may result in reduction of the load bearing capacity of the pile.
- 4.** Ensure the Reinforcement cage, inspection pipes etc. shall be placed into the pile shaft.
- 5.** Concreting shall be done continuously by use of the tremie method in clean hole.
- 6.**Temporary boring casing shall be withdrawn concurrently, with concreting to the instructed level, except where sand flow condition exists.
- 7.** After hardening of concrete, top section of the concrete pile shall be broken carefully to reach sound concrete. The reinforcement in the pile shall be exposed for full anchorage length to permit it to be adequately bonded into the pile cap.

B) Approval of Construction Method

In the tender, the Contractor shall describe the construction method he proposes, including name of proposed Sub-contractor (if any), information on boring equipment, materials, method of work and control of quality. The Contractor shall submit references from similar jobs carried out by him and/or his proposed Sub-contractor.

During contract negotiations, the Contractor shall submit all requested supplementary detailed information in writing.

After the Contract has been awarded, the Contractor shall prepare a detailed programme and establish a procedure for the pile construction. The detailed programme shall contain all required information on materials, equipment, methods of work etc. and be approved in writing by the Engineer. Such approval shall not, however, relieve the Contractor of his responsibilities for pile construction.

The import of any boring equipment or materials by the Contractor, before he has received the Engineer's approval of proposed construction methods, shall be at the Contractor's risk.

4.1.3.2 Setting out Piles

The Contractor shall check the casing position for each pile during and immediately after placing the casing, and agree it with the Engineer. Survey marker for the pile position shall be set out and installed by the contractor. The position and verticality of auger, casing shall be checked immediately prior to installation.

4.1.3.3 Diameter of Piles

The diameter of a pile shall be not less than the specified diameter.

4.1.3.4 Tolerances

The centre of the completed pile at the cut off level shall not deviate more than ~~400~~ 50 mm from the theoretically correct position shown on the Drawings. The inclination of the pile shall not deviate more than 1:100 from vertical. The Contractor shall provide suitable equipment, such as an inverted pendulum, to check the verticality of the boreholes at intervals during drilling and prior to concreting.

4.1.3.5 Boring**A) Methods**

Method of excavation shall be proposed by the Contractor and approved by the Engineer. Water or air jetting for boring of the piles shall not be allowed. However, following methods may be considered as general guideline, pending variance imposed by soil condition or other factors:

Sl.	Drilling method	Pile Diameter
1	Boring by PERCUSSION METHOD using Direct Mud Circulation (DMC) or Bailer and Chisel technique by tripod and mechanical winch machine. Tube well boring machine shall not be used	400 mm diameter 600 mm diameter 750 mm diameter 900 mm diameter
2	Boring by Skid Mounted Mechanical Table Drive Rotary Boring/ Spindle Type Rotary Drilling Machine. Tube well boring machine/ Bailer and chisel technique by tripod and mechanical winch machine shall not be used.	900 mm diameter 1000 mm diameter 1200 mm diameter
3	Boring by HYDRAULIC ROTARY METHOD using Crawler mounted, telescopic boom hydraulic piling rig. Tube well boring machine/ Bailer and chisel technique by tripod and mechanical winch machine/ Skid Mounted Mechanical Table Drive Rotary Boring/ Spindle Type Rotary Drilling Machine shall not be used.	900 mm diameter 1000 mm diameter 1200 mm diameter 1500 mm diameter 1800 mm diameter 2000 mm diameter 2500 mm diameter
4	Driven Cast-in-Situ vertical R.C.C. pile of specified diameter and length (length to be measured from the bottom of pile cap to the bottom of shoe), to carry safe working load not less than specified, including cost of shoe & all other materials and labour for casting, hoisting, driving etc. and also including cost of dummy lengths of pile and of hire charges of all instruments as necessary but excluding concrete & reinforcement etc. all complete as per drawing, specification and direction of Engineer-in-Charge.	400 mm diameter 600 mm diameter 750 mm diameter 900 mm diameter 1000 mm diameter 1200 mm diameter 1500 mm diameter

Boring Near Recently Cast Piles

Piles shall not be bored so close to other piles which have recently been cast and which contain workable or unset concrete so that a flow of concrete could be induced from or damage caused to any of the piles. Boring and excavation for a pile shall not be commenced until 24 hours after completion of any pile within a radius of $6D$ (or as directed by the Engineer), Where D is the centre to centre diameter of the pile.

B) Temporary Casings

Temporary casing of approved quality or an approved alternative method shall be ~~used~~ installed to sufficient depth to maintain the stability of pile excavations, which might otherwise collapse, and ensure that fragments of soil from the sides of the hole do not drop into the concrete as it is placed.

Temporary casings shall be free from significant distortion. They shall be of uniform cross-section throughout each continuous length. During concreting they shall be free from internal projections and encrusted concrete which might prevent the proper formation of piles. A minimum of 3 m of casing shall be provided at the top of the borehole to prevent loose soil from falling into the excavation, unless otherwise approved by the Engineer based on site-specific geotechnical conditions

C) Stability of Pile Excavation Using Drilling Fluid

The drilling fluid shall be maintained at a level so that the water or fluid pressure always exceeds the pressure exerted by the soils and external ground water. The fluid level (water or slurry) inside the borehole shall be maintained at least 2 metres above the river water level or any artesian pressure level throughout boring and until concreting is completed using a tremie pipe, to ensure borehole stability and prevent collapse of the penetrated strata.

In the event of a rapid loss of water or bentonite suspension from the pile excavation, the excavation shall be backfilled without delay and the instructions of the Engineer shall be obtained before excavation at that location is resumed.

D) Disposal of Excavated Material

No excavated material shall be dumped into the river or any connecting waterway without the written approval of the Engineer. Excavated material shall be removed from site and dumped either beyond areas affected by dredging, or taken to the Contractors approved dumping areas on land. The Contractor shall be fully responsible for costs involved in removing the excavated material to spoil.

E) Pumping from Boreholes

Pumping from a borehole shall not be permitted unless a casing has been placed into a stable stratum which prevents the flow of water from other strata in significant quantities into the boring, or unless it can be shown that pumping will not have a detrimental effect on the surrounding soil or property.

F) Obstructions

Where boulders or other obstructions render it impossible to bore the pile, excavation operations inside pile casing as directed by the Engineer shall be carried out to remove obstructions exceeds 200 mm and the obstruction is found more than 2 metres below river bed before remedial design-

G) Unexpected Ground Conditions

The Contractor shall report immediately to the Engineer any circumstances which indicate that in the Contractor's opinion the ground conditions differ from those expected by him from his interpretation of the site investigation reports.

H) Boring Records

During the boring of the pile, the Contractor shall compile a 'boring log' indicating depths and types of the various soil layers encountered. Disturbed samples shall be submitted to the Engineer as requested.

The Contractor shall allow for carrying out sampling and tests to check soil strengths as required by the Engineer.

I) Final Pile Toe Level

The final pile toe level shall be as indicated on the Drawing or as instructed by the Engineer after due consideration of the Contractor's proposals, boring logs and test results.

The final toe level of other piles may subsequently be altered according to the results of the test loadings detailed in Section 4.4.

J) Inspection and Cleaning Bottom of Excavation

The time between final excavation and bottom cleaning and the start of concreting shall be kept as short as possible and shall not exceed 6 hours. To achieve this, the final 2 metres of excavation shall not start until all preparations for cleaning, reinforcing and concreting are finished. In case of unexpected delay the Contractor shall dump sand or gravel in the bore to 2 metres above toe level.

On completion of the drilling an interval is required, to allow the fine materials to settle (15 minutes unless otherwise approved by the Engineer). Thereafter the bottom of the excavation shall be carefully cleaned of mud, sedimentation and other soft material by an approved method.

The Contractor shall show, to the satisfaction of the Engineer, that the bottom of the excavation is clean. Sedimentation tests shall be carried out by the Contractor in the presence of the Engineer.

If boring without casing, the diameter of the boring hole for a representative number of piles shall be measured by caliper prior to the placing of concrete. The verticality of boreholes will be checked as directed by the Engineer. These measurements shall be done by the Contractor using approved equipment and no reimbursement shall be made.

4.1.3.6 Placing Reinforcement

The reinforcement shall be placed as indicated on the Drawings. Reinforcement in the form of a cage shall be assembled with additional support, such as spreader forks and lacings, necessary to form a rigid cage. Hoops, links or helical reinforcement shall fit closely around the main longitudinal bars and be bound to them by approved wire, the ends of which shall be turned into the interior of the pile or pour. Reinforcement shall be placed and maintained in position.

The cover to all reinforcement shall be not less than 75 mm.

Joints in longitudinal steel bars shall be permitted unless otherwise specified. Joints in reinforcement shall be such that the full strength of the bar is effective across the joint and shall be made so that there is no relative displacement of the reinforcement during the construction of the pile.

Joints in longitudinal bars in piles with tension (for instance for test loading) shall be carried out by welding unless another method has been approved by the Engineer.

If the final pile toe level instructed by the Engineer is deeper than that indicated on the Drawings, the section of the pile deeper than the toe level indicated on the Drawings is not required to be reinforced, unless otherwise instructed by the Engineer. No bend in reinforcement at toe of the pile is allowed as it prevents proper clearing and concreting of pile.

4.1.3.7 Placing Concrete

A) Approval

No concreting shall take place before the bottom of the excavation has been cleaned, the borehole inspected and approval obtained in writing from the Engineer.

The method for placing concrete requires to be approved and conform to the following:

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- The method of placing and the workability of the concrete shall be such that a continuous monolithic concrete shaft of the full cross section is formed.
- The concrete shall be placed continuously, and without such interruption as would allow the previously placed batch to have hardened. In this respect the Contractor shall submit details of his contingency plans, standby plant etc. to be utilized in the event of an equipment failure.
- The use of pumped concrete and the methods in its use shall be approved.
- The Contractor shall take all precautions in the design of the mix and placing of the concrete to avoid arching of the concrete in a casing. No spoil, liquid or other foreign matter shall be allowed to contaminate the concrete.
- Care shall be taken during concreting of bored cast-in-situ piles to prevent segregation of concrete. The displacement or distortion casing shall also be avoided.

B) Workability of Concrete

Slump measured at the time of discharge into the pile boring shall be in accordance with Table 4.1-1.

Table 4.1-1

Piling Mix Workability	Slump		Typical Conditions of Use
	Minimum (mm)	Range (mm)	
A	75	75 - 150	Placed into water-free unlined or permanently lined bore of 600 mm diameter or over, or where casting level lies below temporary casing: reinforcement widely spaced, leaving ample room for free movement of concrete between bars.
B	100	100 - 200	Where reinforcement is not spaced widely; where cut-off level of concrete is within temporary casing; where pile bore is water-free and the diameter is less than 600 mm.
C	150	150 or more	Where concrete is to be placed by tremie under water or drilling mud or by pumping.

C) Placing Concrete Under Water or Drilling Fluid

Concrete to be placed under water or drilling fluid shall be placed by tremie and shall not be discharged freely into the water or drilling fluid.

Before placing concrete, the Contractor shall ensure that there is no accumulation of silt, other material, or heavily contaminated bentonite suspension at the base of the boring, which could impair the free flow of concrete from the pipe of the tremie. A sample of the bentonite suspension shall be taken from the base of the boring using an approved sampling device. If the specific gravity of the suspension exceeds 1.25, the placing of concrete shall not proceed. In this event the Contractor shall modify the mud quality and brought down to range at 1.02 to 1.10.

The concrete shall be a rich coherent mix of high workability in accordance with Section 4.1.2.2 and shall be placed in such a manner that segregation does not occur.

During and after concreting, care shall be taken to avoid damage to the concrete from pumping and dewatering operations.

The hopper and pipe of the tremie shall be clean and watertight throughout. The pipe shall extend to the base of the boring and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the pipe of the tremie and the water or drilling fluid. The pipe shall at all times penetrate the concrete, which has previously been placed and shall not be withdrawn from the concrete until completion of concreting. The bottom of the tremie pipe shall be kept at least 1.5 metres under the surface of concrete once that amount of concrete has been placed. At all times a sufficient quantity of concrete shall be maintained within the pipe to ensure that the pressure from it exceeds that from the water or drilling fluid. The internal diameter of the pipe of the tremie shall be not less than 150 mm for concrete made with 20 mm aggregate and not less than 200 mm for concrete made with 40 mm aggregate. It shall be so designed that external projections are minimized, allowing the tremie to pass through reinforcing cages without causing damage. The internal face of the pipe of the tremie shall be free from projections. All tremie tubes shall be thoroughly cleaned after use.

The Contractor shall maintain a continuous record of the volume of concrete used and the level of the concrete in the pile. Any deviations from the theoretical, or expected, volume/level relationship shall be immediately reported to the Engineer.

4.1.3.8 Extraction of Temporary Casing

A) Workability of Concrete

Temporary casings shall be extracted while the concrete within them remains sufficiently workable to ensure that the concrete is not lifted.

B) Concrete Level

When the casing is being extracted a sufficient quantity of concrete shall be maintained within it to ensure that pressure from external water, drilling fluid or soil is exceeded and that the pile is neither reduced in section nor contaminated. The toe of the temporary casing shall be kept a minimum of 2 metres under the outlet of the tremie.

No concrete shall be placed in the boring once the bottom of the casing has been lifted above the top of the concrete; it shall be placed continuously as the casing is extracted until the desired head of concrete is obtained.

Adequate precautions shall be taken in all cases where excess heads of water or drilling fluid could be caused as the casing is withdrawn because of the displacement of water or fluid by the concrete as it flows into its final position against the walls of the shaft.

The pile shall be concreted with a certain over height to allow for chiseling off the top concrete down to sound hard concrete.

The pile top shall, after clean cutting, be embedded 100 mm in the foundation.

C) Vibrating Extractors

The use of vibrating casing extractors shall be permitted.

D) Reinforcement Cage

During concreting and pulling the casing, the reinforcement cage shall be secured against uplift and the top shall be kept under close inspection.

E) Supervision

The execution of the pile concreting shall be supervised by a qualified person of the Contractor's staff, who will keep records on the relation between quantity of concrete used, level of concrete and withdrawal of casing.

4.1.3.9 Temporary Support

The Contractor shall ensure that free standing piles are temporarily braced or stayed immediately after driving to prevent loosening of the piles in the ground and to ensure that no damage resulting from oscillation, vibration or movement of any free-standing pile length can occur.

4.1.3.10 Records

The Contractor shall keep records as indicated below for the installation of each pile and shall submit two signed copies of these records to the Engineer not later than noon of the next working day after the pile was installed. The signed records shall form a record of the work. The following data are required:

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- a) Pile location
- b) Pile reference number
- c) Pile type
- d) Nominal cross-sectional dimensions or diameter
- e) Date and time of boring
- f) Date and time of concreting
- g) River bed level at commencement of installation of pile
- h) Working level
- i) Pile toe level
- j) River water levels
- k) Pile head level
- l) Length of temporary casing
- m) Length of permanent casing
- n) Soils samples taken and in situ tests carried out
- o) Standing water level
- p) Length and details of reinforcement
- q) Concrete mix
- r) Volume of concrete supplied to pile and corresponding levels of concrete and casings
- s) All information regarding obstructions, delays and other interruptions to the sequence of work.

4.1.3.11 Measures in Case of Rejected Piles

If any pile is found unsatisfactory in the opinion of the Engineer for utilization in the structure, it shall be cut off below the pile cap if so ordered by the Engineer. The pile shall be replaced as directed by the Engineer.

When the safe bearing value of any pile is found by test to be less than the design load, longer piles or additional piles shall be installed as ordered by the Engineer.

4.1.4 Measurement

The unit of measurement for bored cast in place piling shall be the linear metre of pile constructed and accepted in the structure. The payable lengths of the satisfactory bored piles shall be measured from the toe level to cut off 100 mm above the bottom level of pile cap. Pile permanent steel casing shall be measured separately in linear metres of the installed and accepted length of casing that remains in the finished structure. Reinforcement steel shall be measured in accordance with Specifications Section 5.2.4.

4.1.5 Payment

Bored piles shall be paid for at the Contract unit price per linear metre. The rate shall constitute full compensation for all materials including temporary casings & concrete and integrity testing of pile (The integrity test shall be done as per Clause no 4.3.7), but excluding reinforcement steel and Permanent Steel Casing, which items will be paid for separately. The rate shall also include boring equipment, standard penetration testing, split

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spoon sampling & testing,, boring, excavation, concreting, inspection and control, cutting off, welding, coupling and all related tools, rigs, cranes, jets, frames, leads, labour, and other incidental equipment and work necessary to complete the work.

Payment for bored cast in place pilot piles (see Section 4.4.1.2(e) for definition of pilot pile), completed and accepted, shall be made at the Contract unit price per linear metre for providing piles of the size specified. When pilot piles are incorporated in the foundation as working piles, no additional payment shall be made for the piles.

Payment for reinforcement steel shall be at the Contractor's rates per tonne for mild steel and high yield deformed steel bars.

Payment for Pile Permanent Steel Casing shall be at the Contract unit price per linear metre. The rate shall constitute full compensation for all materials, labour and plant necessary for providing and installing the casing, including all jointing, testing and coatings.

No payment shall be made for unauthorized, defective, unsound or unsatisfactorily piles or for any costs incurred by the Contractor for such piles.

Payment for testing of piles shall be made separately, as detailed in Section 4.4.

Pay items shall be:

04/01/01(a)	Bored Cast in Place Piles (Dia 400mm)	Linear Metre
04/01/01(b)	Bored Cast in Place Piles (Dia 600mm)	Linear Metre
04/01/01(c)	Bored Cast in Place Piles (Dia 750mm)	Linear Metre
04/01/01(d)	Bored Cast in Place Piles (Dia 900mm)	Linear Metre
04/01/01(e)	Bored Cast in Place Piles (Dia 1000mm)	Linear Metre
04/01/01(f)	Bored Cast in Place Piles (Dia 1200mm)	Linear Metre
04/01/01(g)	Bored Cast in Place Piles (Dia 1500mm)	Linear Metre
04/01/01(h)	Bored Cast in Place Piles (Dia 2000mm)	Linear Metre
04/01/01(i)	Bored Cast in Place Piles (Dia 2500mm)	Linear Metre
04/01/01(j)	Boring by PERCUSSION METHOD using Direct Mud Circulation (DMC) or Bailer and Chisel technique by tripod and mechanical winch machine (Dia 400, 600, 750 & 900 mm)	Linear Metre

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04/01/01(k)	Boring by Skid Mounted Mechanical Table Drive Rotary Boring/ Spindle Type Rotary Drilling Machine. (Dia 900, 1000 & 1200 mm)	Linear Metre
04/01/01(l)	Boring by HYDRAULIC ROTARY METHOD using Crawler mounted, telescopic boom hydraulic piling rig. (Dia 900, 1000, 1200, 1500, 1800, 2000 & 2500 mm)	Linear Metre
04/01/01(m)	Driven Cast-in-Situ vertical R.C.C. pile of specified diameter and length (length to be measured from the bottom of pile cap to the bottom of shoe), to carry safe working load not less than specified, including cost shoe & all other materials and labour for casting, hoisting, driving etc. and also including cost of dummy lengths of pile and of hire charges of all instruments as necessary but excluding concrete & reinforcement etc. all complete as per drawing, specification and direction of Engineer-in-Charge. (Dia 400, 600, 750, 900, 1000, 1200 & 1500 mm)	Linear Metre
04/01/03	Mild Steel Reinforcing Bars	Tonne
04/01/04	High Yield Deformed Steel Reinforcing Bars	Tonne
04/01/05(a)	Permanent Steel Casing (6mm thick, dia 400mm)	Linear Metre
04/01/05(b)	Permanent Steel Casing (6mm thick, dia 600mm)	Linear Metre
04/01/05(c)	Permanent Steel Casing (6mm thick, dia 750mm)	Linear Metre
04/01/05(d)	Permanent Steel Casing (10mm thick, dia 600mm)	Linear Metre
04/01/05(e)	Permanent Steel Casing (10mm thick, dia 750mm)	Linear Metre
04/01/05(f)	Permanent Steel Casing (10mm thick, dia 900mm)	Linear Metre
04/01/05(g)	Permanent Steel Casing (10mm thick, dia 1000mm)	Linear Metre
04/01/05(h)	Permanent Steel Casing (10mm thick, dia 1200mm)	Linear Metre
04/01/05(i)	Permanent Steel Casing (12mm thick, dia 1500mm)	Linear Metre
04/01/05(j)	Permanent Steel Casing (16mm thick, dia 2000mm)	Linear Metre
04/01/05(k)	Permanent Steel Casing (20mm thick, dia 2500mm)	Linear Metre

4.2 PRECAST CONCRETE DRIVEN PILES

4.2.1 Description

This work shall consist of precast reinforced or prestressed concrete piles furnished and driven in accordance with these Specifications and in conformity with the requirements shown on the Drawings or elsewhere in the Contract Documents.

The type and sizes of piling to be used shall be as indicated on the Drawings. Where precast concrete driven piles have been used for the design, the Engineer shall consider and may give approval for the use of alternative types of piling proposed by the Contractor. The Contractor in submitting an alternative type of pile shall provide design data, piling experience records and calculations supporting the pile design and any variations in the substructure.

4.2.2 Materials

4.2.2.1 Concrete

Precast concrete piles shall be constructed in accordance with the details shown on the Drawings, and of the concrete class, proportions, method of mixing and placing in accordance with the provisions of Section 5.1. Concrete class shall be minimum 30, and all cement used shall be type 1 (Sulphate resistant cement shall be used for saline area) and concrete shall contain not less than 350 kg of cement per m³.

Any face of a pile shall not deviate by more than 6 mm from a straight edge 3 metres long laid on the face, and the centroid of any cross section of the pile shall not deviate by more than 1/1,000 of the length of the pile from the straight line connecting the centroids of the end faces of the pile.

4.2.2.2 Formwork

The formwork for of any shape (square, circular, hexagonal etc.) precast concrete piles shall conform to the general requirement for concrete formwork as described in Section 5.1.

The head of each pile shall be square to the longitudinal axis. The corners of the head and the corners of the pile shaft for a distance of 300 mm from the head shall be chamfered 25 mm x 25 mm in case square pile.

4.2.2.3 Prestressing Steel

All prestressing steel shall comply with the general provisions of Section 5.3. All prestressing tendons shall comply with the details shown on the Drawing as to the quality, size, position and prestressing force introduced to the pile.

4.2.2.4 Reinforcement

Reinforcement steel shall be in accordance with the provisions set out in Specifications Section 5.2 and positioned as shown on the Drawings.

4.2.3 Production of Piles

4.2.3.1 Casting

Piles shall be cast in a horizontal position. Special care shall be taken to place the concrete so as to produce a pile free from any air pockets, honeycombing or other defect.

Concrete shall be placed continuously and shall be compacted by vibrating or by other means satisfactory to the Engineer. The forms shall be slightly overfilled, the surplus concrete screeded off, and the top surfaces finished to a uniform, even texture similar to that produced by the forms.

Piles may only be constructed in separate shorter elements with the approval of the Engineer. Joints made after casting and/or stressing shall be at least as strong as the piles themselves in every respect.

4.2.3.2 Tensioning Procedure (Prestressed Piles Only)

Tensioning shall be carried out only in the presence of the Engineer, or his representative, unless otherwise approved in writing.

As used here the word “tendon” shall be defined as any single prestressing element used to apply prestressed forces to the concrete. For pretensioning this shall be each strand or straight wire.

All tendons to be stressed in a group shall be brought to a uniform tension of approximately 500 kilograms per tendon prior to being given their full tension. After this initial stressing the group shall be stressed to a total tension as required on the Drawings by means of hydraulic jacks or other approved appliances equipped with gauges graduated to read directly to 1% of the total load applied, and calibrated to measure accurately the stress induced in the steel. This induced stress shall be measured by elongation of the tendons and checked by gauge pressure. The results obtained shall be within 5% of each other.

Means shall be provided for measuring the elongation to an accuracy of one millimetre in twenty metres of length between jacking heads. In the event of apparent discrepancies of more than five percent between stresses indicated by gauge pressure and elongation, the entire operation shall be checked carefully and the source of error determined and corrected before proceeding further.

Independent references shall be established adjacent to each anchorage to indicate any yielding or slippage that may occur between the time of initial stressing and final release of the tendons.

4.2.3.3 Curing

Curing of the concrete shall be commenced prior to the formation of surface shrinkage cracks and as the concrete has hardened sufficiently to prevent injury. Curing shall conform to the requirements of Section 5.1.

4.2.3.4 Release (Pretensioned Piles Only)

For precast pretensioned members the tendon stress shall be maintained between anchorages until the concrete has reached a compressive strength equal to the “Transfer Strength” specified on the Drawings. After strength requirements are attained, the tension in the tendons shall be gradually and simultaneously released and the tendons cut off as required in such a way as to prevent shock. It shall be the Contractor's responsibility to transfer the prestress safely and to the Engineer's satisfaction in all respects.

A recess shall be cut at the ends of piles around each tendon to allow cutting off the tendon and filling the recess with grout so that the cover to the end of the tendon is not less than 20 mm.

4.2.3.5 Finishing

Piles shall present a true, smooth, even surface free from any surface blemishes and true to the dimensions shown on the Drawings, within the tolerance limits.

4.2.3.6 Marking of Piles

After a pile has been cast, the date of casting, reference number, length and, where appropriate, the prestressing force shall be clearly inscribed on the top surface of the pile and also clearly and legibly marked on the head of the pile. In addition, each pile shall be marked at intervals of 250 mm along the top 3 metres of its length before being driven.

4.2.3.7 Handling and Storage of Piles

The method and sequence of lifting, handling, transporting and storing piles shall be such that the piles are not damaged. The lifting point of each size of pile shall be proposed by the Contractor with supporting calculations for approval of the Engineer which verifies the pile will not be damaged during lifting, handling, transporting and storage. The lifting point shall be marked on the pile. During transport and storage, piles shall be stored on adequate supports located under the lifting points of the piles.

Concrete shall at no time be subjected to loading, including its own weight, which will induce a compressive stress in it exceeding one third of its strength. For this purpose, the assessment of the strength of the concrete and of the stresses produced by the loads shall be subject to the agreement of the Engineer.

All piles within a stack shall be in groups of the same length. Packings of uniform thickness shall be provided between piles at the lifting points. Piles shall be stacked at least 300mm above firm level ground unless otherwise specified by the Engineer, which is not liable to unequal subsidence as settlement under weight of the stack of piles. Separate stacks shall be provided for piles of different lengths or types to facilitate identification and handling.

4.2.3.8 Spliced Piles

Where the Drawings do not detail any splices in piles, the Contractor may adopt spliced piles provided details of the splicing method and drawings are submitted to the Engineer for approval prior to the manufacture of the piles.

4.2.4 Driving Piles

4.2.4.1 Strength of Piles

Piles shall not be driven until the concrete has achieved the specified 28 day strength of concrete.

4.2.4.2 Leaders and Trestles

At all stages during driving and until incorporation in the superstructure, the pile shall be adequately supported and restrained by means of leaders, or other guide arrangements to maintain position and alignment and to prevent buckling. These arrangements shall be such that damage to the pile does not occur. Leaders shall be of sufficient length to make the use of followers unnecessary.

4.2.4.3 Driving Equipment

Before any piling work is commenced the Contractor shall submit to the Engineer full details of the pile driving equipment and the method he intends to use in carrying out the work.

For special types of piling, driving head mandrels, or other devices in accordance with requirements shall be provided so that piles may be driven without injury.

The driving equipment shall be of a type which assures that the energy needed to penetrate the pile to the required depth is transmitted to the pile head without damaging the pile. Efficiency factor of the hammer, i.e. the relation between the theoretical energy developed by the hammer and the energy submitted to the pile, shall be minimum 0.7.

Piles shall be driven with hydraulic machines and/or steam, air, diesel or gravity hammers. When diesel hammers are used, they shall be calibrated by load tests if necessary.

When gravity hammers are used for driving concrete piles, the drop height of the hammer shall not exceed 1 metre and the hammer shall have a weight of not less than 80% of the weight of the pile and the driving head. The fall shall be regulated so as to prevent injury to the pile.

The minimum energy developed by other types of hammers shall be the same as specified for gravity hammers.

4.2.4.4 Driving Procedure and Redrive Checks

Each pile shall be driven continuously until the specified or approved set and/or depth has been reached, except that the Engineer may permit the suspension of driving if he is satisfied that the rate of penetration prior to the cessation of driving will be substantially re-established on its resumption or if he is satisfied that the suspension of driving is beyond the control of the Contractor. A follower (long dolly) shall not be used.

The Contractor shall inform the Engineer without delay if an unexpected change in driving characteristics is noted. A detailed record of the driving resistance over the full length of the nearest available pile shall be taken if required.

At the start of work and in a new area or section, sets shall be taken at intervals during the last 3 metres of the driving to establish the behaviour of the piles.

The Contractor shall give adequate notice and provide all facilities to enable the Engineer to check driving resistances. A set shall be taken only in the presence of the Engineer unless otherwise approved.

Redrive checks, if required, shall be carried out to an approved procedure.

4.2.4.5 Final Set

The final set of each pile shall be recorded either as the penetration in millimetres per 10 blows or as the number of blows required to produce a penetration of 250 mm.

When a final set is being measured, the following requirements shall be met:

- a) The exposed part of the pile shall be in good condition without damage or distortion.
- b) The dolly and packing, if any, shall be in sound condition.
- c) The hammer blow shall be in line with the pile axis and the impact surfaces shall be flat and at right angles to the pile and hammer axis.
- d) The hammer shall be in good condition and operating correctly.
- e) The temporary compression of the pile shall be recorded if required.

4.2.4.6 Driving Sequence and Risen Piles

Piles shall be driven in a sequence approved by the Engineer to minimize heave and lateral displacement, particularly in cohesive or loose soils. In dense or stiff soils, driving may proceed from the center outward; in soft soils, from the outside inward to restrain soil movement. The Contractor shall monitor heave and lateral displacement during driving, with corrective measures (e.g., re-driving or repositioning) approved by the Engineer.

When required, levels and measurements shall be taken to determine the movement of either the ground or of any pile which results from the driving process.

When a pile has risen as a result of adjacent piles being driven, the Contractor shall submit to the Engineer his proposals for correcting this and the avoidance of it in subsequent work.

4.2.4.7 Jetting

Water jetting shall not be allowed. Continuous vibratory percussive methods shall be used to drive a pile to both its design depth as well as the required set where the upper strata afford high resistance to driving.

4.2.4.8 Length of Piles

The lengths of the piles shown on the Drawings are based on information which has been obtained from a site investigation prior to the driving of test piles.

Before pile lengths are finally settled, the Contractor shall construct to the lengths shown on the Drawings such pilot piles as may be found necessary and these piles shall be driven in the positions specified by the Engineer who shall be notified in advance of the driving. The Contractor shall furnish the Engineer daily with a detailed record of the pilot piles for the full depth of driving. After attaining the approved set, driving shall be continued until the Engineer directs that it shall cease. Length of working pile shall be reviewed and determined based on load test of pilot piles or service piles, as directed by the Engineer.

Reference is made to Section 4.4 with regard to load tests on selected pilot piles.

4.2.4.9 Repair or Damaged Pile Heads

When repairing the head of a pile, the head shall be cut off square at sound concrete, and all loose particles shall be removed by wire brushing, followed by washing with water. If the pile is to be subjected to further driving, the head shall be replaced with concrete of an approved grade.

If the driving of a pile has been accepted but sound concrete of the pile is below the cut-off level, the pile shall be made good to the cut-off level with concrete of a grade not inferior to that of the concrete of the pile.

Repaired piles shall not be driven until the added concrete has reached the specified characteristic strength of the concrete of the pile.

4.2.4.10 Cut off and Extension

Prestressed concrete piles shall be cut off at such elevation that they shall extend into the cap or footing as indicated on the Drawings. In the case of hollow core piles starter bars shall be cast into the core at the top of the piles and extended into the cap or footing, all as shown on the Drawings. Extensions to prestressed concrete piles shall generally not be permitted, unless a provision for lengthening prestressed piles was incorporated at the time of manufacture. Any method for lengthening shall be such that joints are capable of taking safely the stresses during driving and under load.

4.2.4.11 Damage to Adjacent Structures and Services

The Contractor will take all necessary precautions to avoid damage to any adjacent structures and services. If during the execution of the work damage is, or is likely to be, caused to any adjacent structures or services, the Contractor shall submit to the Engineer his proposals for repair or avoidance of such damage.

4.2.4.12 Records

The Contractor shall keep records as indicated below of the installation of each pile and shall submit two signed copies of these records to the Engineer not later than noon of the next working day after the pile is installed. The signed records shall form a record of the work.

The following data are required:

- a) Pile location
- b) Pile reference number
- c) Pile type
- d) Nominal cross-sectional dimensions or diameter
- e) Length of preformed pile
- f) Date and time of driving or redriving
- g) Ground level at commencement of installation of pile
- h) Working level
- i) Pile toe level
- j) Type, weight, drop and mechanical condition of hammer and equivalent information for other equipment
- k) Number and type of packing used and type and condition of dolly used during driving the pile
- l) Set of pile in mm per 10 blows or number of blows per 250 mm of penetration
- m) If required, the sets taken at intervals during the last 3 metres of driving
- n) If required, temporary compression of ground and pile from time of a marked increase in driving resistance until pile reaches its final level
- o) All information regarding obstructions delays and other interruptions to the sequence of work

4.2.5 Tolerances**4.2.5.1 Setting Out**

Setting out shall be carried out from the main grid lines of the proposed structure. Before installation of the pile, the pile position shall be agreed with the Engineer and marked with suitable identifiable pins or markers.

4.2.5.2 Position

For a pile cut off at or above ground level the maximum permitted deviation of the pile centre from the centre point shown on the setting out drawing shall be 75 mm in any direction. An additional tolerance for a pile head cut off below ground level shall be permitted in accordance with Sections 4.2.5.3 and 4.2.5.4.

4.2.5.3 Verticality

The maximum permitted deviation of the finished pile from the vertical shall be 1 in 50.

4.2.5.4 Rake

The piling rig shall be set and maintained to attain the required rake. The maximum permitted deviation of the finished pile from the specified rake shall be 1 in 25.

4.2.5.5 Dimension

The variation in cross-sectional dimension (e.g., width, diameter) shall be limited to $\pm 10\text{mm}$, $\pm 50\text{ mm}$ for total length, and 1% (10 mm/m) for deviation from straightness along the pile's longitudinal axis.

4.2.6 Defective Piles

The procedure of driving the piles shall not subject them to excessive and undue abuse producing crushing and spalling of the concrete or deformation of the steel. Manipulation of piles to force them into proper position, considered by the Engineer to be excessive, shall not be permitted. Any pile damaged by reason of internal defects, or by improper driving or driven out of its proper location or driven below the elevation fixed by the plans or by the Engineer, shall be corrected at the Contractor's expense by one of the following methods approved by the Engineer for the pile in question:

- 1) The pile shall be withdrawn and replaced by a new and if necessary, a longer pile.
- 2) A second pile shall be driven adjacent to the defective or low pile.
- 3) The pile shall be spliced or built up as otherwise provided herein or a sufficient portion of the footing extended to properly embed the pile.

4.2.7 Measurement

The unit of measurement shall be the linear metre of pile furnished, driven and accepted in the structure. The pay lengths of the satisfactorily driven piles shall be measured from the toe to the cut off.

Cut off lengths shall not be measured for payment.

Reinforcement steel and prestressing reinforcement shall be measured in accordance with Specifications Section 5.2.4. & 5.3.4 respectively.

4.2.8 Payment

Precast concrete driven piles shall be paid for at the Contract unit rate per linear metre. The rate shall constitute full compensation for all materials but excluding reinforcement (prestressed or non-prestressed), which shall be paid for separately. The rate shall also include all shoes, equipment, hardware, formwork etc., driving, cutting off, lengthening and splicing, welding and coupling and all related tools, rigs, cranes, boilers, hammers, leaders, labour and other incidental equipment and work.

Payment for precast concrete driven pilot piles (see Section 4.4.1.2(e) for definition of pilot pile), completed and accepted, shall be made at the Contract unit price per linear metre for providing piles of the size specified. When pilot piles are incorporated in the foundation as working piles, no additional payment shall be made for the piles.

Payment for reinforcement steel shall be at the Contractor's rates per tonne for mild steel and high yield deformed steel bars.

No payment shall be made for unauthorized, defective, unsound or unsatisfactorily driven piles or for any costs incurred by the Contractor for such piles.

Payment for testing of piles shall be made separately, as detailed in Section 4.4.

Pay items shall be:

04/02/01(a)	Driven Precast Piles (150mm X 150mm)	Linear Metre
04/02/01(b)	Driven Precast Piles (200mm X 200mm)	Linear Metre
04/02/01(c)	Driven Precast Piles (300mm X 300mm)	Linear Metre
04/02/01(d)	Driven Precast Piles (350mm X 350mm)	Linear Metre
04/02/01(e)	Driven Precast Piles (400mm X 400mm)	Linear Metre
04/02/01(f)	Driven Precast spliced Piles (300mm X 300mm)	Linear Metre
04/02/01(g)	Driven Precast spliced Piles (350mm X 350mm)	Linear Metre
04/02/01(h)	Driven Precast spliced Piles (400mm X 400mm)	Linear Metre

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	Circular pile of dia 300mm, 400mm, 500mm and 600mm	Linear Metre
04/02/02	Driven Precast Pilot Piles (Dimensions as indicated on the Drawings and stated in the Bill of Quantities)	Linear Metre
04/02/03	Mild Steel Reinforcing Bars	Tonne
04/02/04	High Yield Deformed Steel Reinforcing Bars	Tonne
04/02/04 (b)	Grade 60 (420 MPa) Deformed Steel Reinforcing Bars	Tonne
04/02/04 (c)	Grade 72.5 (500 MPa) Deformed Steel Reinforcing Bars	Tonne
04/02/04 (d)	Grade 80 (550 MPa) Deformed Steel Reinforcing Bars	Tonne
04/02/05 (e)	Prestressing wire of strand	Tonne

4.3 PRECAST CONCRETE UNITS FOR RIVER TRAINING AND RETAINING STRUCTURES

4.3.1 Description

This work shall consist of furnishing and placing all precast members of retaining and river training structures and anchor arrangements, all in accordance with these Specifications and in conformity with the requirements on the Drawings or of other parts of the Contract Documents.

The precast structures consist essentially of precast and driven “I” shaped concrete piles (King Posts) laterally supporting precast concrete planks. The king posts may be laterally anchored through tie bars to raker piles.

4.3.2 Materials

The king posts and raker piles shall conform to the requirements of Section 4.2.2.

The precast concrete planks shall be constructed in accordance with the details shown on the Drawings, and in accordance with Sections 5.1 and 5.2. Cement used shall be type 1.

4.3.3 Construction Methods

4.3.3.1 King Post & Anchor Piles

All production and construction methods for king posts and anchor piles shall conform to Sections 4.2.3 and 4.2.4 except that load testing shall not normally be required.

4.3.3.2 Precast Planks

The precast planks shall be placed between the king posts as shown on the Drawings. The planks shall be excavated or driven down to the levels indicated on the Drawings or as otherwise directed. In this connection it may be necessary to clear up the bed to the prescribed level and make local excavations along the planks as they are lowered. The method of placing the planks shall be agreed with the Engineer.

4.3.4 Tolerances

The horizontal position of the king posts after being driven shall not deviate from the correct position more than ± 10 mm perpendicular to the line of the wall and ± 10 mm in the direction of the wall. The precast planks in between the piles are designed to allow for a longitudinal tolerance of king post position of ± 10 mm. If the Contractor during construction establishes that the above tolerance is too small, the Engineer may accept minor changes in the tolerance. Such changes will require corresponding changes in plank sizes.

4.3.5 Measurement

King posts shall be measured by linear meter in accordance with Section 4.2.7. No distinction shall be made for different sizes or shapes of king posts which shall be as shown on the Drawings.

Precast planks shall be measured by square meter of plank used.

Raker piles shall be measured by cubic metre in accordance with Section 4.2.7. No distinction shall be made for different sizes or rakes of raker piles which shall be as shown on the Drawings. Tie bars shall not be measured separately but are deemed included in the rate for raker piles.

Reinforcement steel in king posts and raker piles shall be measured in accordance with Specifications Section 5.2.4. Reinforcement steel in precast planks shall not be measured separately.

4.3.6 Payment

The Contractor's rates for king posts and raker piles will constitute full compensation for the supply of all materials excluding reinforcement steel, which shall be paid for separately. The rates shall also include handling, placing and all other related works.

The Contractor's rate for precast planks will constitute full compensation for the supply of all materials including reinforcement steel, handling, placing, driving of raker piles and all other related works. Stone protection, if required, will be measured and paid for separately in accordance with Section 6.

Pay items shall be:

04/03/01	King Post	Cubic Metre
04/03/02	Raker Piles (including Tie Bars)	Cubic Metre

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04/03/03	Precast Planks (including Reinforcement Steel)	Square Metre
04/03/04	Mild Steel Reinforcing Bars to King Posts and Raker Piles	Tonne
04/03/05	High Yield Deformed Steel Reinforcing Bars to King Posts and Raker Piles	Tonne

4.3.7 PILE INTEGRITY TEST

4.3.7.1 Description

Non-destructive testing, such as low strain integrity testing per ASTM D5882, may be conducted to verify pile integrity, with methods and frequency approved by the Engineer. Pile Integrity test is to be performed by the Procuring Entity through BRRL or Bridge unit Professionals or any reputed organization appointed by the Engineer on a number of constructed working piles at the location of each abutment and pier position of a structure to verify the integrity of the installed piles. The apparatus for the Integrity Test shall be selected and arranged by the testing organization. Tests shall be carried out only under the direction of experienced and competent professionals conversant with the test equipment and test procedure.

4.3.7.2 Test procedure

All piles are to be selected for testing. With the permission from the Design unit selected piles can be tested. The contractor shall provide detailed records as recorded during installation of each pile which is to be tested. The contractor shall cut down all pile heads at the cut off level or otherwise prepare the piles for testing as required by the Engineer. The pile head shall be formed to give plane surface which is normal to the axis of the pile. The reinforcement of the pile shall be bent in such a way to ease the testing.

4.3.7.3 Results of Testing

Pile Integrity test or sonic test is a quick method to check the continuity of pile shape and size up to desired level. This method detects pile defects like cracks, Breaking, Necking, soil intrusion and variation of pile shape. The final length can also be measured indirectly. If any pile after Integrity test is found unsatisfactory in the opinion of the Engineer for utilization in the structure, the pile shall be replaced as suggested by the design unit and directed by the Engineer/Project Manager. All extra expenses shall be borne by the contractor and payment shall be made in accordance with clause 4.1.3.11 of these specifications.

4.3.7.4 Measurement

The unit of measurement shall be number of pile tested.

4.3.7.5 Payment

The test performed in the number of piles shall be paid for at the rate charged by the approved testing organization. The rate shall constitute full compensation for all materials, equipments and labour for test purpose. The payment shall be made by the contractor to the test performer and the amount shall be reimbursed to the contractor by the procuring Entity from the provisional sum as indicated in the bill of quantities.

The bill for integrity test shall not be paid separately to the contractor because it is already included in the item number 4.1.5.

Pay items shall be:

PIT on 10 (ten) nos. piles or less of a single bridge	Set	
Additional charge on Mobilization & demobilization beyond 100 km of Dhaka / nearby source to site	Per km	
PIT on each additional pile after 10(ten) piles tested	Each	

4.4 PILE TEST LOADING**4.4.1 Descriptions****4.4.1.1 General**

This Section deals with the testing of a pile by the application of an axial load or force. It covers vertical piles tested in compression.

4.4.1.2 Definitions**A) Allowable Load**

The load which may be safely applied to a pile after taking into account its ultimate bearing capacity, negative friction, pile spacing, overall bearing capacity of the ground below and allowable settlement.

B) Compression Pile

A pile which is designed to resist an axial force such as would cause it to penetrate further into the ground.

C) Kentledge

The dead weight used in a loading test.

D) Maintained Load Test

A loading test in which each increment of load is held constant either for a defined period of time or until the rate of movement (settlement or uplift) falls to a specified value.

E) Pilot Pile

A pile installed before the commencement of the main piling works or a specific part of the works for the purpose of establishing the suitability of the chosen type of pile and for confirming its design, dimensions and bearing capacity. Pilot piles may be utilized as working piles, subject to the Engineer's approval.

F) Proof Load

A load applied to a selected pile to confirm that it is suitable for the load at the settlement specified. Proof loads typically range from 150–200% of working load, with higher loads (e.g., 300%) for specific cases approved by the Engineer.

G) Reaction System

The arrangement of kentledge, piles, anchors or rafts that provides a resistance against which the pile is tested.

H) Tension Pile

A pile which is designed to resist an axial force such as would cause it to be extracted from the ground.

I) Test Pile

Any pile to which a test loading is, or is to be, applied.

J) Ultimate Bearing Capacity

The load at which the resistance of the soil becomes fully mobilized.

K) Working Load

The load which the pile is designed to carry.

L) Working Pile

One of the piles forming the foundation of a structure.

M) Dynamic Load

A transient or cyclic load applied to a pile during testing or installation, such as impact forces from a drop hammer or pile driver, to evaluate its bearing capacity, integrity, or driving response

4.4.2 Supervision

All tests shall be carried out only under the direction of an experienced and competent supervisor conversant with the test equipment and test procedure. All personnel operating the test equipment shall have been trained in its use.

4.4.3 Safety Precautions**4.4.3.1 General**

When preparing for, conducting and dismantling a pile test the Contractor shall carry out the requirement of the various regulations and other statutory instruments that are applicable to the work for the provision and maintenance of safe working conditions, and shall in addition make such other provision as may be necessary to safeguard against any hazards that are involved in the testing or preparations for testing.

4.4.3.2 Kentledge

Where kentledge is used the Contractor shall construct the foundations for the kentledge and any cribwork, beams or other supporting structure in such a manner that there will not be differential settlement, bending or deflection of an amount that constitutes a hazard to safety or impairs the efficiency of the operation. The kentledge shall be adequately bonded, tied or otherwise held together to prevent it falling apart, or becoming unstable because of deflection of the supports.

The weight of kentledge shall be greater than the maximum test load and if the weight is estimated from the density and volume of the constituent materials an adequate factor of safety against error shall be allowed.

4.4.3.3 Tension Piles and Ground Anchors

Where tension piles or ground anchors are used the Contractor shall ensure that the load is correctly transmitted to all the tie rods or bolts. The extension of rods by welding shall not be permitted unless it is known that the steel will not be reduced in strength by welding. The bond stresses of the rods in tension shall not exceed normal permissible bond stresses for the type of steel and grade of concrete used.

4.4.3.4 Testing Equipment

In all cases the Contractor shall ensure that when the hydraulic jack and load measuring device are mounted on the pile head the whole system shall be stable up to the maximum load to be applied. Means shall be provided to enable dial gauges to be read from a position

clear of the kentledge stack or test frame so that failure in any part of the system due to overloading, buckling, loss of hydraulic pressure will not constitute a hazard to personnel.

The hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure shall be capable of withstanding a test pressure of 1.5 times the maximum working pressure without leaking.

The maximum test load or test pressure expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.

4.4.4 Construction of a Pilot Pile to be Test Loaded

4.4.4.1 Notice of Construction

The Contractor shall give the Engineer at least 48 hours notice of the commencement of construction of any pilot pile, which is to be test loaded.

4.4.4.2 Method of Construction

Each pilot test pile shall be constructed in a manner similar to that to be used for the construction of the working piles, and by the use of similar equipment and materials. Any variation shall only be permitted with prior approval.

Extra reinforcement and concrete of increased strength shall be permitted in the shafts of pilot piles at the discretion of the Engineer.

4.4.4.3 Boring or Driving Record

For each pilot pile which is to be tested a detailed record of the soils encountered during boring, or of the progress during driving shall be made and submitted to the Engineer daily not later than noon on the next working day.

4.4.4.4 Cut-Off Level

The pile shaft shall terminate at the normal cut-off level, or at a level required by the Engineer.

The pile shaft shall be extended where necessary above the cut-off level of working piles so that gauges and other apparatus to be used in the testing process are not damaged by water or falling debris.

4.4.4.5 Pile Head for Compression Tests

For a pile that is tested in compression, the pile head or cap shall be formed to give a plane surface which is normal to the axis of the pile, sufficiently large to accommodate the loading and settlement-measuring equipment and adequately reinforced or protected to prevent damage from the concentrated application of load from the loading equipment.

4.4.5 Preparation of a Working Pile to be tested

If a test is required on a working pile the Contractor shall cut down or otherwise prepare the pile for testing as required by the Engineer in accordance with Sections 4.4.4.4 and 4.4.4.5.

4.4.6 Reaction Systems

4.4.6.1 Compression Tests

Compression tests shall be carried out using kentledge, tension piles or specially constructed anchorages.

Where kentledge is to be used, it shall be supported on cribwork disposed around the pile head so that its centre of gravity is on the axis of the pile. The bearing pressure under supporting cribs shall be such as to ensure stability of the kentledge stack. Kentledge shall not be carried directly on the pile head, except when directed by the Engineer.

4.4.6.2 Working Piles

Where working piles are used as reaction piles their movement shall be measured to within an accuracy of 0.5 mm.

4.4.6.3 Spacing

Where kentledge is used for loading vertical piles in compression, the distance from the edge of the test pile to the nearest part of the crib supporting the kentledge stack in contact with the ground shall be not less than 1.3 metres.

The centre to centre spacing of vertical reaction piles, including working piles used as reaction piles, from a test pile shall be not less than three times the diameter of the test pile or the reaction piles or 2 metres, whichever is the greatest.

4.4.6.4 Adequate Reaction

The size, length and number of the piles or anchors, or the area of the rafts, shall be adequate to transmit the maximum test load to the ground in a safe manner without excessive movement or influence on the test pile.

4.4.6.5 Care of Piles

The method employed in the installation of any reaction piles, anchors or rafts shall be such as to prevent damage to any test pile or working pile.

4.4.6.6 Loading Arrangement

The loading arrangement used shall be designed to transfer safely to the test pile the maximum load required in testing. Full details shall be submitted to the Engineer prior to any work related to the testing process being carried out on the Site.

4.4.7 Equipment for Applying Load

The equipment used for applying load shall consist of one or more hydraulic rams or jacks with the total capacity of the jacks being at least equal to the required maximum load. The jack or jacks shall be arranged in conjunction with the reaction system to deliver an axial load to the test pile. The complete system shall be capable of transferring the maximum load required for the test.

4.4.8 Measurement of Load

Suitable approved measuring devices for determining the load on the pile shall be supplied by the Contractor. Certificates of calibration shall be supplied to the Engineer.

In addition, large diameter (i.e. exceeding 1.2 metre) test piles shall be instrumented at 5 different depths to measure the load distribution along the piles. The instrumentation shall consist of both a mechanical system and strain gauges for measuring the pile deformation. The mechanical system shall consist of 6 mm steel rods or high tensile steel wires gauge No. 23, placed in steel tubes down to the various depths, and connected to dial gauges at the top. The strain gauges shall be of a stable type, wholly protected by a steel capsule. They shall be welded to the steel reinforcement, 2 gauges at each depth.

The Engineer shall approve the type of gauges to be used and other details on the instrumentation.

4.4.9 Adjustability of Loading Equipment

The loading equipment shall be capable of adjustment throughout the test to obtain a smooth increase of load or to maintain each load constant at the required stages of a maintained loading test.

4.4.10 Measuring Movement of Pile Heads**4.4.10.1 General**

In a maintained load test movement of the pile head shall be measured by two of the methods as described below. One method for settlement measurements, the other method for control.

4.4.10.2 Levelling Method

An optical or any other leveling method by reference to an external datum may be used.

Where a level and staff are used, the level and scale of the staff shall be chosen to enable readings to be made to within an accuracy of 0.5 mm. A scale attached to the pile or pile cap may be used instead of a leveling staff. At least two datum points shall be established on permanent objects or other well-founded structures, or deep datum points shall be installed. Each datum point shall be situated so that only one setting up of the level is needed.

No datum point shall be affected by the test loading or other operations on the site.

Where another method of leveling is proposed this shall be approved in writing.

4.4.10.3 Independent Reference Frame

An independent reference frame may be set up to permit measurement of the movement of the pile. The supports for the frame shall be founded in such a manner and at such a distance from the test pile, kentledge support cribs, reaction piles, anchorages and rafts that movements of the ground in the vicinity of the equipment do not cause movement of the reference frame during the testing. Check observations of any movements of the reference frame shall be made and a check shall be made of the movement of the pile head relative to an external datum during the progress of the test. In no case shall the supports be less than three test pile diameters or 2 metres, whichever is the greater, from the centre of the test pile.

The measurement of pile movement shall be made by two dial gauges rigidly mounted on the reference frame that bear on surfaces normal to the pile axis fixed to the pile cap or head. Alternatively the gauges may be fixed to the pile and bear on surfaces on the reference frame. The dial gauges shall be placed in diametrically opposed positions and be equidistant from the pile axis. The dial gauges shall enable readings to be made to within an accuracy of 0.1 mm.

The reference frames shall be protected from sun and wind.

4.4.10.4 Other Methods

The Contractor may submit for approval any other method for measuring the movement of pile heads.

4.4.11 Protection of Testing Equipment

4.4.11.1 Protection from Weather

Throughout the test period all equipment for measuring load and movement shall be protected from the weather.

4.4.11.2 Prevention of Disturbance

Construction equipment and persons who are not involved in the testing process shall be kept at a sufficient distance from the test to avoid disturbance to the measurement apparatus.

4.4.12 Supervision**4.4.12.1 Notice of Test**

The Contractor shall give the Engineer at least 24 hours notice of the commencement of the test.

4.4.12.2 Records

During the progress of a test, the testing equipment and all records of the test as required in Section 4.4.14.2 shall be available for inspection by the Engineer.

4.4.13 Test Procedure**4.4.13.1 Proof Test by Maintained Load Test**

The maximum load, which shall be applied in a proof test, is shown on the Drawings. The loading and unloading shall be carried out in stages as shown in Table 4.4-1 or as required by the Engineer.

Following each application of an increment of load the load shall be held for not less than the period shown in Table 4.4-1 or until the rate of settlement is less than 0.25 mm/hour and is slowing down. The rate of settlement shall be calculated from the slope of the curve obtained by plotting values of settlement versus time and drawing a smooth curve through the points.

Each stage of unloading shall proceed after expiry of period shown in Table 4.4-1.

For any period when the load is constant, time and settlement shall be recorded immediately on reaching the load and at approximately 15 minute intervals for 1 hour, at 30 minute intervals between 1 hour and 4 hours, and at 1 hour intervals between 4 hours and 12 hours after the application of the increment of load. The Engineer may require that the full loading, or any portion of the loading, be maintained on the pile for periods longer than shown in Table 4.4-1.

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Table 4.4-1

Loading Sequence			
Load as Percentage of Working Load		Minimum Time of	
Bored Piles	Driven Piles	Holding Load	
25	50	1 hour	
50	100	1 hour	
75	125	1 hour	
100	150	1 hour	
75	125	10 minutes	
50	100	10 minutes	
25	50	10 minutes	
0	0	1 hour	
100	150	6 hours	
125	200	1 hour	
150	250	6 hours	
175	275	1 hour	
200	300	24 hours	Proof Load
175	275	10 minutes	
150	250	10 minutes	
125	225	10 minutes	
100	200	10 minutes	
75	150	10 minutes	
50	100	10 minutes	
25	50	10 minutes	
0	0	1 hour	

4.4.14 Presentation of Results

4.4.14.1 Results to be submitted

Results shall be submitted as:

- a) A summary in writing to the Engineer, unless otherwise directed, within 24 hours of the completion of the test, which shall give for a proof test by maintained load for each stage of loading, the period for which the load was held, the load and the maximum settlement or uplift recorded.
- b) The completed schedule of recorded data as in Section 4.4.14.2 within seven days of the completion of the test.

4.4.14.2 Schedule of Recorded Data

The Contractor shall provide information about the tested pile in accordance with the following schedule where applicable.

A) General

- 1) Site location
- 2) Contract identification
- 3) Proposed structure
- 4) Date of test

B) Pile Details

- 1) Identification (number and location of the test pile)
- 2) Ground level at pile position
- 3) Head level as which test load is applied
- 4) Type of pile
- 5) Length in ground
- 6) Level in ground
- 7) Level of toe
- 8) Details of Permanent casing

C) Installation Details

- 1) Dates and times of boring, driving and concreting of test pile and adjacent piles
- 2) Date and time of casting concrete
- 3) Driven length of pile or temporary casing at final set
- 4) Hammer type, size or weight

- 5) Dolly and packing, type and condition before and after driving
- 6) Driving log (depth, blows per 250 mm, interruptions or breaks in driving)
- 7) At final set and at redrive set, for drop or single acting hammers, the length of the drop or stroke, for diesel hammers the length of the stroke and the blows per minutes, for double-acting hammers the number of blows per minute
- 8) Condition of pile head or temporary casing after driving

D) Test Procedure

- 1) Weight of kentledge
- 2) Tension pile, ground anchor or compression pile details
- 3) Plan of test arrangement showing position and distances of kentledge supports, rafts, tension or compression piles and reference frame to test pile
- 4) Jack capacity
- 5) Method of Load measurement
- 6) Method(s) of penetration measurement
- 7) Relevant dates and times

E) Test Results

- 1) In tabular form
- 2) In graphical form: loads plotted against movements and time

4.4.15 Completion of a Test

4.4.15.1 Measuring Equipment

On completion of a test all equipment and measuring devices shall be dismantled, checked and either stored so that they are available for use in further tests or removed from the Site.

4.4.15.2 Kentledge

Kentledge and its supporting structure shall be removed from the test pile and stored so that they are available for use in further tests or removed from the Site.

4.4.15.3 Temporary Piles

On completion of a preliminary test, temporary tension piles shall be cut off below ground level, removed from the Site and the ground made good with approved material as specified.

4.4.16 Lateral Load Test

Performing Lateral load test for test load of 150% of the design lateral load for routine tests, or up to 200% for ultimate capacity, approved by the Engineer in accordance with ASTM D 3966 (Standard Test Methods for Deep Foundations under Lateral Load) on working pile including the cost of arranging kentledge, jacks, platform, reaction frame with required anchorage, island where required, preparing the pile head if necessary, dial gauges, joist and all other necessary arrangement, loading and unloading, submission of the result, removal of all arrangement after completion, cost of all labour, material, carriage, leads and lift etc. complete as per approved drawing, Technical specification and as directed by the Engineer.

Before commencing load test, Contractor shall submit methodology for conducting load test to the Engineer for approval. The Testing firm will be selected taking prior approval of procuring entity. The methodology of lateral load test and driving logs/ boring & pouring logs shall be the part of test report. Lateral Load Test and Report shall be conducted under the supervision of personnel from BRRL or a professional Geotechnical Engineer registered in the Bangladesh Professional Engineers Registration Board (BPERB), Institute of Engineers Bangladesh (IEB).

4.4.16.1 Materials

The standards for all materials (concrete, rebar etc.) used in the construction of the load test shall conform to the relevant drawings, project specifications and RHD Technical Specifications or other applicable standards and methods acceptable to the Engineer.

4.4.16.2 Construction

i) Method of Load Application

Lateral load testing shall begin after Axial Compressive Load tests are completed on the relevant test piles.

The Contractor shall provide the required test loads shown on the Drawings by jacking between two test piles simultaneously using one or more jacks. The minimum distance between the test pile and the reaction pile(s) shall be five test pile diameters. The minimum distance between the test pile and the reaction may be greater than five test pile diameters if not testing the piles simultaneously. The Contractor shall submit method statement of conducting to Lateral Load Test to the Engineer for his review and approval.

The Contractor may request approval for supplying the reaction for the lateral load test by another method. In that case, the Contractor shall submit alternative method statement with appropriate detailed representative Drawings for the approval by the Engineer.

ii) Load Application System

The load shall be applied by means of one or more hydraulic jacks having a total capacity of at least two times the maximum loads shown on the Drawings and in the project specific specifications. The jack load shall be transferred to the test piles by means of steel bearing

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plates that bear firmly against the test piles. Bearings and bearing plates shall be of steel and of sufficient size to accommodate the testing equipment used and to transmit the applied loads without detrimentally high unit pressures. The heads of the piles shall be capped so as to provide plane vertical bearing surfaces for the bearing plates, or the bearing plates shall be set in high-strength grout or adequately welded to the sides of the piles using suitable filler material to provide full bearing against the piles.

All instrumentation and hydraulic jack(s), load cell(s), pump etc. shall be approved by the Engineer.

A. Reference Beam

The reference beam for LVDTs (linearly variable differential transducers) or dial gauges shall be supported on supports firmly anchored at a minimum clear distance of 3 m or as shown on the Drawing from the test piles. The reference beam shall be oriented perpendicular to the line of load application and located at a sufficient distance from the test piles to avoid interference with the test piles throughout the test. The surfaces on which the gage stems bear shall be smooth finished, such as glass or sheet acrylic, attached by a suitable adhesive.

B. Measurement of Lateral Movement of Pile Top

A primary and a secondary movement of test pile shall be measured with an inclinometer or other approved instrument.

iii) Load Procedure

The loading procedure shall be the Standard Loading Procedure specified in ASTM D 3966 and as outlined in the Table below.

Percentage of Design Load	Load Duration (minutes)
0	-
25	10
50	10
75	15
100	20
125	20
150	20
170	20
180	20
190	20
200	60
150	10
100	10
50	10
0	-

Additional cycles of loading or unloading using similar procedures may be required by the Engineer following the completion of the initial test cycle. The Engineer shall decide to terminate the test if an unsafe eccentric loading condition develops as a result of high

or out of-line pile movements. The Contractor shall be responsible for the safety and structural stability of the test.

Tolerance

To determine lateral load capacity, a lateral load test shall be performed with at least two times the proposed design working load as specified in the drawings. Allowable lateral capacity based on BNBC 2020 shall satisfy the following criteria. The safe load on single pile for the initial test should be least of the following:

- 50% of the lateral load at which the pile head displacement is 12mm or lateral load specified to any other specified displacement as per project requirement for performance evaluation.
- Final load at which the total displacement corresponds to 5mm.
- Load corresponding to any other specified displacement at specified locations in single or group piles as per performance requirement.

4.4.16.4 Measurement and Payment

Lateral load tests on large diameter (exceeding 1.2 m) cast-in-situ bored piles shall be conducted on designated test piles or working piles, using working piles as anchor piles in a reaction system. The test pile and anchor piles will be paid for at the normal rates for working piles as provided in Section 4.1. Separate payments will be made for carrying out each load test, individual rates shall be provided for different proof loads, which are specified in the Bill of Quantities. Payment for load tests on large diameter cast in place bored piles shall include provision of special instrumentation to test piles, anchor bars to reaction piles, provision of all testing equipment, carrying out of the tests, dismantling of equipment and removal from site, breaking out pile heads etc. in accordance with the requirements for working piles, preparation of all reports etc.

Load tests on pilot driven piles shall normally be carried out using temporary anchor piles or kentledge. The pilot pile will be paid for at the rates provided for pilot piles in Section 4.2. Separate payment shall not be made for anchor piles. Separate payments will be made for carrying out each load test and individual rates shall be provided for different proof loads, which are specified in the Bill of Quantities. Payment for load tests on pilot driven piles shall include provision of anchor piles or kentledge, provision of all test equipment, carrying out of the tests, dismantling of equipment and removal from site, cutting off below level of temporary anchor piles, preparation of all reports etc.

Load tests on pilot cast in place piles, less than & equal to 1.2 metre diameter, shall normally be carried out using temporary anchor piles or kentledge. The pilot pile will be paid for at the rates provided for pilot piles in Section 4.1. Separate payment shall not be made for anchor piles. Separate payments will be made for carrying out each load test and individual rates shall be provided for different proof loads, which are specified in the Bill of Quantities. Payment for load tests on pilot piles shall include provision of anchor piles or kentledge, provision of all test equipment, carrying out of the tests, dismantling of

equipment and removal from site, cutting off below level of temporary anchor piles, preparation of all reports etc.

Pay items shall be:

04/04/01(a)	Vertical Load Test on Cast in Place Working Pile (Proof load to be specified in BoQ) 50 Ton	Number
04/04/01(b)	Vertical Load Test on Cast in Place Working Pile (For 100 Ton)	Number
04/04/01(c)	Vertical Load Test on Cast in Place Working Pile (For 200 Ton)	Number
04/04/01(d)	Vertical Load Test on Cast in Place Working Pile (As specified in Drawings & BoQ /Drawing)	Number
04/04/02	Vertical Load Test on Cast in Place Pilot Pile (Proof load to be specified in BoQ /Drawing)	Number
04/04/03	Vertical Load Test on Pilot Driven Pile (Proof load to be specified in BoQ /Drawing)	Number
04/04/04(a)	Lateral Load Test (Up to 50 MT capacity pile) (proof load to be specified in BoQ/drawing)	Number
04/04/04(b)	Lateral Load Test (Above 50 MT capacity pile) (proof load to be specified in BoQ/drawing)	Number

4.5 BITUMEN SLIP LAYER FOR PILES

4.5.1 Description

This work shall consist of a bitumen slip layer placed on the upper part of concrete piles before driving.

Bitumen slip layer is provisional, and shall be used only if directed by the Engineer. The use of a slip layer to reduce negative skin friction on the piles will be evaluated after completion of pile load tests.

The bitumen layer shall be used on the upper part of the pile through soft and medium stiff clay. Any shorter length may be decided by the Engineer. This part of the pile shall be

primed and uniformly coated with a bituminous material as specified below. No priming or coating shall be allowed below the designated elevation of the installed pile.

4.5.2 Materials

4.5.2.1 Primer

Before priming, the pile shall be completely clean and dry. The primer shall consist of the relevant bitumen for the slip layer and a petroleum solvent, or RC 250 as decided by the Engineer. The bitumen and the solvent shall be suitably blended to produce a liquid coating which may be applied cold, and which produces a suitable bond between the pile surface and the asphalt enamel. The primer shall have good spraying, brushing and leveling properties and a minimum tendency to produce bubbles during application. It shall be homogeneous and free from water.

The amount of primer shall be 0.2 litre/m², applied with brushing or spraying to achieve a uniform continuous film.

The primer shall be allowed to set thoroughly, for minimum 6 hours or more as needed, before the slip layer is applied.

4.5.2.2 Bitumen

The bitumen slip layer shall consist of a straight run bitumen, penetration grade 80-100.

The bitumen shall be heated to a liquid state, which is approximately 200°C, and applied by brushing or other approved means. The thickness shall be minimum 3 mm.

Special measures such as wrapping sprayed surfaces with suitable paper or plastic sheet shall be taken to prevent the bitumen from flowing and stripping and from damage during handling and storage. During storage the piles shall be protected from sun-heat, and if necessary cooled with spraying of water.

4.5.3 Field Storage and Installation

Precautions shall be taken to prevent damage to the bitumen slip layer during installation as deemed necessary by the Engineer.

Piles shall not be placed directly on the ground: wood sleepers shall always be used. The sleepers shall be placed beneath the uncoated end parts. When lifting piles the wire rope should not be in direct contact with the bitumen slip layer.

4.5.4 Measurement

The unit of measurement shall be square meters of pile covered by bitumen slip layer and accepted by the Engineer. Cut off lengths shall not be measured for payment.

4.5.5 Payment

This work measured as provided above shall be paid for at the Contract unit prices per square metre. The unit rate shall constitute full compensation for all materials, equipment and workmanship necessary to provide the slip layer and the protective layer inclusive of protective metal rings if required, and the additional costs incurred during handling and driving of the piles.

Payment shall only be made if bitumen slip layer is selected and ordered in writing by the Engineer.

Pay item shall be:

04/05/01 Bitumen Slip Layer to Concrete Piles

Square Meter

4.6 DRIVEN BULLAH PILES

4.6.1 Description

This work shall consist of providing and driving wooden piles in accordance with these Specifications and in conformity with the requirements of the Drawings or the Engineer's instructions.

4.6.2 Materials

Bullah piles shall consist of best quality timber; Sal, Sundari, Garzon or equivalent approved by the Engineer. The diameter shall be 200-250 mm and the length shall be such that not less than 4.5 metres of acceptable pile can be driven. Each pile shall be fitted with a metal shoe.

4.6.3 Driving Piles

4.6.3.1 Driving Equipment

Before any piling work is commenced the Contractor shall submit to the Engineer full details of the pile driving equipment and the methods he intends to use in carrying out the work.

4.6.3.2 Leaders and Trestles

At all stage of driving the pile shall be adequately supported and restrained by means of leaders or other guide arrangements to maintain position and alignment. These arrangements shall be such that damage to the pile does not occur.

4.6.3.3 Hammers

Any kind of hammer may be used provided that it is of a type which assures that the energy needed to penetrate the pile to the required depth is transmitted to the pile head without damaging the pile. When gravity hammer are used the drop shall not exceed 1.0 meter. The fall shall be regulated so as to prevent damage to the pile. The efficiency factor of the hammer, i.e., the relationship between the theoretical energy developed by the hammer and the energy transmitted to the pile, shall be a minimum of 0.7.

4.6.3.4 Length of Piles

The length of piles to be driven shall be as shown on the Drawings or as approved or directed by the Engineer. Piles shall be neatly cut off at the specified level.

4.6.3.5 Records

The Contractor shall keep records as indicated below for each pile and submit two signed copies to the Engineer not later than the next working day that a pile is driven.

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- a) Pile Location
- b) Pile Reference Number
- c) Pile Type and Diameter
- d) Date and Time of Driving
- e) Ground Level
- f) Details of Hammer and Drop
- g) Details of any Delay or Interruptions

4.6.4 Measurement

The unit of measurement shall be the linear metre of pile furnished, driven and accepted in the structure. The pay length of the satisfactorily driven piles shall be measured from the toe to the cut off.

Cut off lengths shall not be measured for payment.

4.6.5 Payment

The work measured as provided above shall be paid for at the Contract unit rate per linear meter. The rate shall constitute full compensation for all materials, equipment, driving, cutting off and all related tools, rigs, cranes, hammers, leaders and other incidental equipment and work.

No payment shall be made for unauthorized, defective, unsound or unsatisfactorily driven piles or for any costs incurred by the Contractor for such piles.

Pay item shall be:

04/06/01(a)	Driven Bullah Piles (Dia 125-150mm)	Linear Meter
04/06/01(b)	Driven Bullah Piles (Dia 150-175mm)	Linear Meter
04/06/01(c)	Driven Bullah Piles (Dia 175-200mm)	Linear Meter
04/06/01(d)	Driven Bullah Piles (Dia 200-225mm)	Linear Meter

4.7 Well Foundations

4.7.1 Description

This work shall consist of construction of well foundation, taking it down to the founding level through all kinds of sub-strata, plugging the bottom, filling the inside of the well, plugging the top and providing a well cap in accordance with the details shown on the drawings and as per these Specifications, or as directed by the Engineer.

Wells may have a circular, rectangular or D-shape in plan and may consist of one, two or more compartments in plan. The outer wall of the well, known as well Steining may be cellular.

The process of taking down the well to the founding level is known as well sinking. After reaching the founding level, the hollow inside the well, (“dredge hole”) is plugged at the bottom by concrete (“bottom plug”). The dredge hole is then filled with approved filling up to the level indicated on the drawings and provided with a concrete plug (“top plug”).

To facilitate sinking of well, steel cutting edge is fabricated and connected to a concrete well curb of required shape. On top of the well curb, adequate height of well Steining is cast and the process of sinking is carried out. After a portion of the well has been sunk, another height of well Steining is cast on top of the previous section and further sinking carried out. This process is continued till the bottom level of the well reaches the founding level.

At the top of the well Steining, “well cap” is laid which transmits the loads and forces from the sub-structure (piers or abutments) to the foundations.

At least one bore-hole must be available/carried out in accordance with these specifications at each well foundation location, prior to commencement of work. The depth of bore-holes should extend up to a depth equal to one and a half times the outer diameter/ least dimension of the well below the anticipated founding level. In case the well foundation is to rest on a rocky strata, it may be necessary to undertake additional borings/probings prior to commencement of work to ascertain the actual profile and the quality of the rocky strata, at the level at which the well has to be seated, etc.

4.7.2 Materials

4.7.2.1 Steel cutting edge

The mild steel cutting edge shall be made from structural steel sections and shall be strong enough to facilitate sinking of the well through the type of strata expected to be encountered. The weight of the cutting edge shall not be less than 40 kg per metre length and be properly anchored into the well curb, as shown in the drawing.

When there are two or more compartments in a well, the bottom end of the cutting edge of the inner walls of such wells shall be kept at about 300 mm above that of outer walls.

In V shaped cutting edge, the inclined plate should meet the vertical plate in such a way that full strength connection by welding is feasible.

4.7.2.2 Concrete

The concrete for well curb/Steining, Bottom & Top plug, and well cap shall conform to section 5.1 of these specifications.

4.7.2.3 Reinforcement

The reinforcement shall conform to section 5.2 of these specifications.

4.7.2.4 Sand

Sand for filling the inside of well shall be non-plastic and free from vegetable matter, soft particles and clay. It shall conform to either grading B or grading C of table 2.8-1 of these specifications.

4.7.3 Construction Methods

4.7.3.1 Setting Out and Preparations for Sinking

Necessary reference points shall be fixed, away from the zone of blow-ups or possible settlements resulting from well sinking operations. Such reference points shall be connected to the permanent theodolite stations with the base line on the banks. The center of the individual wells shall be marked with reference to these stations. The distance, wherever practicable, shall be checked with the help of accurate tapes and precision distomat. Reference points shall also be fixed to mark X-X axis (usually traffic direction) and Y-Y axis (normal to X-X axis) accurately. A temporary bench mark shall also be established near the well foundation, away from the zones of blow-ups or possible settlement. The bench mark shall be checked regularly with respect to the permanent bench mark established at the bridge site.

For wells which are to be located in water, an earthen or sand island shall be constructed. Sand islands are practicable for water depths of about 5 m under stable bed soil conditions. For greater depths or in fast flowing rivers or for locations where soil is too weak to sustain Sand Island, floating caissons may have to be adopted.

The plan dimensions of sand islands shall be such as to have a working space of at least 2 m all around the Steining. The dimension of the sand islands shall however be not less than twice the dimension in plan of the well or caisson. Sand islands shall be maintained to perform their functions, until the well is sunk to a depth below the bed level at least equal to the depth of water.

Sand Island shall be protected against scour and the top level shall be sufficiently above the prevailing water level to be decided by the Engineer so that it is safe against wave action.

While sand islands are constructed at well location, floating caissons are generally fabricated at or near the banks on dry land or dry docks. Floating caissons are towed into position in floating condition.

For well placed in the banks of the river or in the dry area, the bed may be prepared by excavating the soil up to 1.5 m followed by leveling and dressing before placing the cutting edge.

4.7.3.2 Cutting Edge Erection

The parts of cutting edge shall be erected on level firm ground. Temporary supports shall be provided to facilitate erection and maintaining the assembly in true shape. The fabrication may be carried out in the shop or at site. Steel sections shall not be heated and forced into shape. However, “V” cuts may be made in the horizontal portion, uniformly throughout the length, to facilitate cold bending. After bending, such “V” cuts should be closed by welding. Joints in the lengths of structural sections, unless otherwise specified shall be filler welded using single cover plate to ensure the requisite strength of the original section.

4.7.3.3 Well curb

The well curb shall be such that it shall offer minimum resistance while sinking, but shall be strong enough to be able to transmit superimposed loads from the Steining to the bottom plug. The shape and the outline dimension of the curb as given in Appendix -3 (Fig. 2) of IRC: 78 may be referred for guidance. The internal angle of the curb as shown in Appendix 3 shall be about 30° to 37°, depending upon geotechnical data.

The well curb may be pre-cast or cast-in-situ. The well curb shall be reinforced concrete of minimum grade M 25 with minimum reinforcement of 72 kg/cu.m excluding bond rod. The steel shall be suitably arranged to prevent spreading and splitting of curb during sinking. Steel formwork for well curb shall be fabricated strictly in conformity with the drawing. The outer face of the curb shall be vertical. The bottom ends of vertical bond rods of Steining shall be fixed securely to the cutting edge with check nuts or by welds. The formwork on outer face of curb may be removed within 24 hours after concreting. The formwork on inner face shall be removed after 72 hours. All concreting in the well curb shall be done in one continuous operation.

In case blasting is anticipated, the inner faces of the well curb shall be protected with the steel plates of thickness not less than 10 mm up to the top of the well curb. If it is desired to increase the steel lining above the well curb then the thickness in the extended portion can be reduced to 6 mm. This extra height of the steel shall not exceed 3 m, unless specific requirement exists, as decided by the Engineer. The curb in cases involving blasting, shall be provided with additional hoop reinforcement consisting of 10 mm dia mild steel or deformed bars at 150 mm spacing which shall also extend up to a height of liner.

4.7.3.4 Well Steining

The dimensions, shape, concrete strength and reinforcements of the well shall strictly conform to those shown on the drawings. The formwork shall preferably be of M.S. sheets shaped and stiffened suitably. In case timber forms are used, they shall be lined with plywood or M.S. sheets.

Steining built in the first lift above the well curb shall not be more than 2 m and in subsequent lifts it shall not exceed the diameter of the well or the depth of well sunk below the adjoining bed level at any time. For stability, the first lift of steining shall be cast only after sinking the curb at least partially for stability. Concreting of steining may be carried out in subsequent lifts of about 2 to 2.5 m. Attempts should be made to minimize the number of construction joints. The concreting layers shall be limited to 450 mm restricting the free fall of concrete to not more than 1.5 m. Laitance formed at the top surface of a lift shall be removed to expose coarse aggregates before setting of concrete at the proposed construction joint. As far as possible, construction joints shall not be kept at the location of laps in the vertical steining bars.

The steining of the well shall be built in one straight line from bottom to top such that if the well is tilted, the next lift of steining will be aligned in the direction of the tilt. The work will be checked carefully with the aid of straight edges of lengths approved by the Engineer. Plumb bob or spirit level shall not be used for alignment. After sinking of a stage is complete, damaged portions, if any, of steining at top of the previous stage shall be properly repaired before constructing the next stage.

The height of steining shall be calibrated by making at least 4 gauges (preferably in traffic direction and in a direction normal to traffic direction) distributed equally on the outer periphery of the well each in the form of a 100 mm wide strip painted on the well, with every metre mark shown in black paint. The gauges shall start with zero at the bottom of the cutting edge. Marking of the gauges shall be done carefully with a steel tape.

After reaching the founding level, the well steining shall be inspected to check for any damage or cracks. The Engineer will direct and the Contractor shall execute the remedial measures before acceptance of the well steining. In case the well cannot be accepted even with any remedial measure, then the well shall stand rejected.

4.7.3.5 Well Sinking**4.7.3.5.1 General**

The well shall as far as possible be sunk true and vertical through all types of strata.

Sinking or loading of the well with kentledge shall be commenced only after the steining has been cured for at least 48 hours or as specified in the drawings.

No well shall be permitted to be placed in a pre-dredged hole.

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The well shall be sunk by excavating material uniformly from inside the dredge hole. Use of water jetting, explosives and divers may be adopted for sinking of wells through difficult strata with prior approval of the Engineer.

Normally dewatering of well should not be permitted as a means for sinking the well. It shall never be resorted to if there is any danger of sand blowing under the well. Dewatering shall however be done when well is to be founded into rock. Pneumatic sinking may have to be resorted to where obstacles such as tree trunks, large size boulders, etc. are met at the bottom or when there is a hard stratum which cannot be removed by open dredging. The necessity for pneumatic sinking shall be decided by the Engineer.

Sinking history of well shall be maintained in the format given bellow:

Chart of Sinking

LOWEST BED LEVEL-----

LOWEST WATER LEVEL -----

HIGHT OF FLOOD LEVEL -----

FOUNDATION LEVEL -----

HEIGHT OF CURB -----

HEIGHT OF CUTTING EDGE -----

DATE	STEINING					SINKING					DEPTH OF SUMP BELOW CUTTING EDGE	STRATAMET WITH	KENTLEDGE			QUANTITY OF DREDGED MATERIAL CUBIC METRE	REPORT REGARDING OBSTACLES OR SAND BELOW DURING SINKING	REPORT ANY SPECIAL METHOD OF SINKING EMPLOYED	REMARKS	SIGNATURE OF SUPERVISING OFFICER
	REDUCED LEVEL (RL) OF BOTTOM OF CUTTING EDGE	RL OF TOP OF STEINING BEFORE CASTING	RL OF TOP OF STEINING AFTER CASTING	HEIGHT OF STEINING OF CAST (COL.4 - COL.3)	TOTAL HEIGHT OF STEINING (INCLUDING CURB AND CUTTING EDGE (COL.4-COL.2) METRE	RL OF REFERENCE LEVEL (AT WHICH CUTTING EDGE IS PLACED)	INITIAL GAUGE READING METRE	FINAL GAUGE READING METRE	SINKING DURING THE DAY (COL.9 - COL.8)	RL OF BOTTOM OF CUTTING EDGE (COL.7COL.8)			WEIGHT TONNES	ECCENTRICITY ALONG X AXIS METRE	ECCENTRICITY ALONG Y AXIS METRE					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

4.7.3.5.2 Sand blows in wells

Dewatering shall be avoided, if sand blows are expected. Any equipment or men working inside the well shall be brought outside the well as soon as there are any indications of sand blow. Sand blow often can be minimized by keeping the level of water inside the well higher than the water table and also by adding heavy kentledge.

4.7.3.5.3 Use of Kentledge as Sinking Load

Kentledge shall be placed in an orderly and safe manner on the loading platform and in such a way that it does not interfere with the excavation of the material from inside the dredge hole and also does not in any way damage the steining of the well.

Where tilts are present or there is a danger of well developing a tilt, the position of the load shall be regulated in such a manner as to provide greater sinking effort on the higher side of the well.

4.7.3.5.4 Use of Water Jetting

Water jetting and jack down method may be employed for well sinking as per requirement.

4.7.3.5.5 Use of Explosives

Mild explosive charges may be used as an aid for sinking of the well only with prior permission of the Engineer. Blasting of any sort shall only be done in the presence of the Engineer and not before the concrete in the steining has hardened sufficiently and is more than 7 days old. When likelihood of blasting is predicted in advance, protection of the bottom portion of the well shall be done as per these Specifications.

After blasting operations are completed, the well curb and steining should be examined for any cracks and remedial measures taken.

If blasting has been used after the well has reached the design foundation level, normally 24 hours shall be allowed to lapse before the bottom plug is laid.

The charges shall be exploded well below the cutting edge by making a sump so as to avoid chances of any damage to the curb or to the steining of the well. A minimum sump of 1 m depth should be made before resorting to blasting. Use of large charges, 0.7 kg or above, may not be allowed except under expert direction and with the permissions from the Engineer. Suitable pattern of charges may be arranged with delay detonators to reduce the number of charges fired at a time. The burden of the charge may be limited to 1 m and the spacing of holes may normally be kept as 0.5 to 0.6 m.

All prevalent laws concerning handling, storing and using of explosives shall be strictly followed.

All safety precautions shall be taken as per IS: 4081 "Safety Code for Blasting and related Drilling Operations", to the extent applicable, whenever blasting is resorted to. There

should be no equipment inside the well nor there any worker in the closed vicinity of the well at the time of exploding the charges.

If rock blasting is to be done for seating of the well, the damage caused by flying debris should be minimized by covering blasting holes by rubber mats before blasting.

4.7.3.5.6 Use of Divers

Use of divers may be made both for the sinking purpose like removal of obstructions, rock blasting and for inspection. All safety precautions shall be taken as per any acceptable safety code for sinking with divers or any statutory regulations in force.

Only persons trained in the diving operation shall be employed and shall be certified to be fit for diving by an approved doctor.

They shall work under expert supervision. The diving and other equipments shall be of acceptable standard and certified to this effect by an approved independent agency. It shall be well maintained for safe use.

Arrangement for ample supply of low pressure clean cool air shall be ensured through an armored flexible hose pipe. Standby compressor plant shall be provided in case of breakdown.

Separate high pressure connection for use of pneumatic tools shall be made. Electric lights, where provided, shall be at 50 volts (maximum). The raising of the diver from the bottom of wells shall be controlled so that decompression rate conforms to the rate as laid down in appropriate regulations.

Size of different types of Well:

1. 12750mm X 5500mm (RCC Well)
2. 7940mm X 4270mm (Brick Well)
3. 10000mm X 5000mm (Brick Well)

Size may differ based on designer requirement.

4.7.3.6 Precautions during sinking

- a) When the wells have to be sunk close to each other and clear distance between them is not greater than the diameter of wells, sinking shall be taken up on all wells and they shall be sunk alternately so that sinking of wells proceeds uniformly. Simultaneous and even dredging shall be carried out in the wells in such a manner that the difference in the levels of the sump and cutting edge in the adjacent wells does not exceed half the clear gap between them. Plugging of all the wells shall be done together.
- b) During sinking of dumb-bell or double D-shaped wells, the excavation in both the dredge holes should be carried out simultaneously and equally.

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- c) Bore chart shall be referred to constantly during sinking for taking adequate care while piercing different types of strata. The type of soil as obtained during the well sinking should be compared with bore chart so as to take prompt decisions.
- d) Before seasonal floods, all wells on which sinking is in progress shall be sunk to sufficient depths below the designed scour level. Further, they shall be temporarily filled and plugged so that they do not suffer any tilt or shift during the floods.
- e) All necessary precautions shall be taken against any possible damage to the foundations of existing structures in the vicinity of the wells, prior to commencement of dredging from inside the well.
- f) The dredged material shall not be allowed to accumulate over the well. It shall be dumped and spread, as far away as possible, and then continuously and simultaneously removed, as directed by the Engineer. In case the river stream flows along one edge of the well being sunk, the dredged material shall not be dumped on the dry side of the bank but on the side on which the river current flows.
- g) Very deep sump shall not be made below the well curb, as it entails risk of jumping (sudden sinking) of the well. The depth of sump shall be generally limited to one-sixth of the outer diameter/least lateral dimension of the well in plan. Normally the depth of sump shall not exceed 3.0 m below the level of the cutting edge unless otherwise specially permitted by the Engineer.
- h) In case a well sinks suddenly with a jerk, the steining of the well shall be examined to the satisfaction of the Engineer to see that no damage has occurred to it.
- i) In pneumatic sinking, the well shall not, at any time, be dropped to a depth greater than 500 mm by the method of "blowing down".
- j) Dewatering shall be avoided if sand blows are expected. Any equipment and men working inside the well shall be brought out of the well as soon as there are any indications of a sand-blow.
- k) Sand blowing in wells can often be minimized by keeping the level of water inside the well higher than the water table and also by adding heavy kentledge.
- l) In soft strata prone to settlement/creep, the construction of the abutment wells shall be taken up only after the approach embankment for a sufficient distance near the abutment has been completed.

4.7.3.7 Tilts and Shifts

The inclination of the well from the vertical is known as tilt and the horizontal displacement of the center of the well at the founding level from its theoretical position is known as shift.

Unless otherwise specified, the tilt of any well shall not exceed 1 (horizontal) in 80 (vertical), and the shift at the well base shall not be more than 150 mm in any resultant direction.

Tilts and shifts shall be carefully checked and recorded in the format vide Appendix 1200/II regularly during sinking operations. For the purpose of measuring the tilts along the two axes of the bridge, reduced level of the marks painted on the surface of the steining of the well shall be taken. For determination of shift, locations of the ends of the two diameters shall be precisely measured along the two axes, with reference to fixed reference points.

Whenever any tilt is noticed, adequate preventive measures like placing eccentric kentledge, pulling, strutting, anchoring or dredging unevenly and depositing dredge material unequally, putting obstacles below cutting edge. Water jetting etc., shall be adopted before any further sinking. After correction, the dredged material shall be spread out uniformly.

A pair of wells close to each other has a tendency to come closer while sinking. Timber struts may be introduced in between the steining of these wells to prevent tilting. The chart of tilt and shifting of well is given below:

CHART OF TILT AND SHIFTING IN WELL NO:

DATE	TOTAL	TOTAL	REDUCED LEVELS (RL'S) OF GAUGE MARKS						TILT			SHIFT			ACTION TAKEN FOR RECTIFI CATION	REMARKS	SIGNATURE OF SUPERVISOR G OFFICER
	STEINING	SINKING	ALONG X-AXIS			ALONG Y-AXIS			TILT	TILT	RESULTANT TILT (COL10 ² +COL11 ²) ^{1/2}	ALONG X-AXIS WITH	ALONG Y-AXIS WITH	(COL13 ² + COL14 ²) ^{1/2}			
			(PLACE) END	(PLACE) END	DIFFERENCE	(U/S)	(D/S)	DIFFERENCE	ALONG X-	ALONG Y-		DERECTION	DERECTION				
			(COL-5- COL-4)			(COL-8- COL-7)			AXIS	AXIS							
	METRE	METRE			METRE			METRE	DIVIDED BY WELL DIA	DIVIDED BY WELL DIA		METRE	METRE				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

Tilts occurring in a well during sinking in dipping rocky strata can be safeguarded by suitably supporting the curb.

In the event of a well developing tilt or shift beyond the specified permissible values, the Contractor shall have to carry out, at his own cost, suitable remedial measures to the satisfaction of the Engineer, to bring the tilt and shift within permissible values.

If the resultant tilt and / or shift of any well exceed the specified permissible values, generally it should not exceed 1 in 50 and 300 mm respectively. The well so sunk shall be regarded as not conforming to specifications and a sub-standard work. The Engineer in his sole discretion may consider accepting such a well, provided:

i) Calculations for foundation pressures and steining stresses, accounting for the actual tilt and shift furnished by the Contractor show that the well is safe. Remedial measures required to bring the stresses within permissible values (such as increase in the dimension of the well cap, provision of dummy weights on the well cap etc.), shall be carried out by the Contractor at his own cost.

ii) The Contractor shall be subjected to reduction in rates as a penalty in accordance with Clause 4.7.5(g).

In case the Engineer, in his discretion, rejects the well, the Contractor shall dismantle the rejected well to the extent directed by the Engineer and remove the debris. Further, the Contractor shall, at his own risk and cost, complete the bridge with modified span arrangement acceptable to the Engineer.

4.7.3.8 Floating caissons

Floating caissons may be of steel, reinforced concrete or any suitable material. They shall have at least 1.5 m free board above the water level and increased, if considered necessary, in case there is a possibility of caissons sinking suddenly owing to reasons, such as scour likely to result from lowering of caissons, effect of waves, sinking in very soft strata, etc.

Well caissons should be checked for stability against over-turning and capsizing while being towed and during sinking, due to the action of water current, wave pressure, wind etc.

The floating caisson shall not be considered as part of foundation unless proper shear transfer at the interface is ensured.

4.7.3.9 Seating of Wells

The well shall be uniformly seated at the founding strata. It shall be ensured by test borings that the properties of the soil encountered at the founding strata and up to a depth of one and a half times the well diameter is identical to that adopted in the design. The procedure for test borings shall satisfy the provisions of these specifications. In case the soil encountered is inferior to that adopted in design, the well shall be re-designed by the Engineer adopting the soil properties actually encountered and the founding level intimated to the Contractor, who shall carry out the work accordingly.

In case of seating of wells in hard rocky strata, where the rock profile is steeply sloping, pneumatic methods of sinking may be adopted to seat the well evenly as directed by the Engineer. The decision of adopting pneumatic sinking shall be taken by the Engineer. The cutting edge may also be embedded for a suitable depth in the rocky strata, as decided by the Engineer keeping in view the quality of rock. As an additional measure of safety, the well shall be anchored to the rocky strata by anchor bars provided in the steining of the well, as shown on the drawing irrespective of the fact that tension develops or not at the base of the well under design loads. After the well has been evenly seated on good hard rock, arrangements shall be made to facilitate proper inspection in dry and visible conditions before the bottom plug is laid.

4.7.3.10 Bottom Plug

The bottom plug shall be provided in all wells and the top shall be kept not lower than 300 mm in the centre above the top of the curb, as shown in Appendix-3 of IRC:78. A suitable sump shall be below the level of the cutting edge. Before concreting the bottom plug, it shall be ensured that its inside faces have been cleaned thoroughly.

The concrete mix used in bottom plug shall have a minimum cement content of 330 kg per cu.m with a slump about 150 mm to permit easy flow of concrete through tremie to fill up all cavities. Concrete shall be laid in one continuous operation till the dredge hole is filled to the required height. For under water concrete, the concrete shall be placed by tremie under still water condition and the cement content of the mix be increased by 10 percent. Admixtures, if required may be added to the concrete to achieve the required characteristics.

In case of grouted concrete, the grout mix shall not be leaner than 1:2. It shall be ensured that the grout fills up all interstices up to the top of the bottom plug by suitable means such as, controlling the rate of pumping etc.

Any dewatering required, shall be done 14 days after concreting of bottom plug.

The concrete production equipment and placement equipment should be sufficient to enable under water concreting within stipulated time. Necessary standby equipment should be available for emergency situation.

Before commencing plugging, all loose material from the bottom of the well shall be removed.

Concreting shall be done in one continuous operation till the dredge hole is filled up to the required height and thereafter sounding shall be taken up to ensure that the concrete has been laid to the required height.

Least disturbance shall be caused to the water inside the well while laying concrete in the bottom plug.

Concrete shall not be disturbed in any way for at least 14 days.

In order to check any rise in the level of the bottom plug soundings should be taken at the close of concreting and once every day for the subsequent 3 days.

The soundness of the bottom plug may be tested by dewatering the well by 5 m below the surrounding water level and checking the rise of water. The rate of rise shall preferably be less than 10 cm per hour. In case the rate is higher, suitable remedial measures as directed by the Engineer, shall be taken by the Contractor at his own cost.

4.7.3.11 Sand Filling

Sand filling shall commence after a period of 14 days of laying of bottom plug. Also, the height of the bottom plug shall be verified before starting sand filling.

Sand shall be clean and free from earth, clay clods, roots, boulders, shingles, etc. and shall be compacted as directed. Sand filling shall be carried out up to the level shown on the drawing or as directed by the Engineer.

4.7.3.12 Top Plug

After filling sand up to the required level a plug of 300 mm thick concrete shall be provided over it as shown on the drawing or as directed by the Engineer.

4.7.3.13 Well cap

A reinforced cement concrete well cap will be provided over the top of the steining in accordance with the drawing. Formwork will be prepared conforming to the shape of well cap. Concreting shall be carried out in dry condition. A properly designed false steining may be provided where possible to ensure that the well cap is laid in dry condition.

The bottom of the well cap shall be laid preferably as low as possible but not below the LWL, taking in to account for this purpose, the water level prevalent at the time of casting, where the bed level is higher than the LWL, the bottom of the well cap may be suitably raised. Bond rods of steining shall be anchored into the well cap.

4.7.3.14 Tolerances

The permissible tilt and shift shall not exceed 1 (horizontal) in 80 (vertical) and the shift at the well base shall not be more than 150 mm in any resultant direction.

For the well steining and well cap, the permissible tolerances shall be as follows:

a)	Variation in dimension	:	+50 mm, -10 mm
b)	Misplacement from specified position in plan	:	15 mm
c)	Surface irregularities measured with 3 m		
	straight edge	:	5 mm
d)	Variation of level at the top	:	± 25 mm

4.7.3.15 Tests and standards of acceptance

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

4.7.4 Measurement

All quantities shall be measured from the drawing, or as ordered by the Engineer, except those required to be provided by the Contractor at his cost.

- a) The cutting edge shall be measured in tonnes based on the net weight of metal used in it.
- b) The concrete in curb, well steining and well cap shall be measured in cubic metres in each of the items as per Section 5.1.4. The reinforcements shall be measured in tonnes separately in each of the items, as per Section 5.2.4.
- c) The measurement for well sinking shall be made in running metres for different depths and in different types of strata (for example, predominantly sand/clay soil, soft rock, hard rock, etc.) as specified in the Contract. The depth of sinking shall be measured from the level specified in the Contract. If no level has been specified in the Contract, sinking shall be measured from the low water level or from the level at which the cutting edge was laid, whichever is higher.
- d) The quantity of concrete in bottom and top plug shall be measured in cubic metres as per Section 5.1.4.
- e) The quantity of sand filling shall be measured in cubic metres.

4.7.5 Payment

All quantities shall be measured from the drawing or as ordered by the Engineer, excepting those required to be provided by the Contractor at his cost.

- a) The Contract unit rates of cutting edge shall cover all costs of labour, material, tools, plant and equipment, including placing in position, sampling and testing, and, supervision, all as per respective Section of Structural Steel Work and as described in this section.
- b) The Contract unit rates for concrete in curb, steining, bottom plug, top plug and well cap, shall cover all costs of labour, material, tools, plant and equipment, formwork and staging including placing in position, sampling and testing, and, supervision, all as per respective Section of Structural Concrete and as described in this section.
- c) The Contract unit rates for reinforcement in curb, steining, and well cap, shall cover all costs of labour, material, tools, plant and equipment, including bending to shape, placing in position, sampling, testing and supervision, all as per respective Section of Steel Reinforcement and as described in this section.

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- d) The Contract unit rates for sand filling shall cover all costs of labour, material, tools, plant and equipment, including placing in position, sampling testing and supervision, all as described in this section.
- e) The Contract unit rates for sinking shall cover the costs of labour, tools, and equipment and plant and for all operations and other incidentals for sinking of well including seating excepting provisions of pneumatic sinking as described in this Section. The unit rates shall specify the strata such as types of soil, rock, etc. The rate shall cover all testing and supervision required for the work.
- g) Reduction in contract unit rates for sinking as a penalty, in pursuance of Clause 4.7.3.14

If any well with tilt and/or shift exceeding the permissible values is accepted by the Engineer, the Contractor shall be subjected to a reduction in the rates for payments as follows:

Sl. No.	Amount of tilt and/or shift	Percent deduction on the rate (s) for sinking of whole well
1.	Tilt exceeding the specified permissible value but equal to or within 1 in 60	5 percent
2.	Tilt exceeding 1 in 60 but equal to or within 1 in 50	10 percent
3.	Tilt exceeding 1 in 50	20 percent
4	Shift exceeding the specified permissible value but equal to or within 200 mm	2 percent
5.	Shift exceeding 200mm but equal to or within 300mm	5 percent
6.	Shift exceeding 300 mm	10 percent

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Pay items shall be:

04/07/01	Cutting Edge (Well Shoe)	Ton
04/07/02(a)	Class-20 Concrete for RCC Well	cum
04/07/02(b)	Class-25 Concrete for RCC Well	cum
04/07/02(c)	Class-30 Concrete for RCC Well	cum
04/07/03	Concrete in Top/Bottom Plugging	cum
4/07/04(a)	Labor for Well Sinking (Size 5000mm X 10000mm) Depth 0m-6m	Metre
4/07/04(b)	Labor for Well Sinking (Size 5000mm X 10000mm) Depth 6m-12m	Metre
4/07/04(c)	Labor for Well Sinking (Size 5000mm X 10000mm) Depth 12m-18m	Metre
4/07/04(d)	Labor for Well Sinking (Size 5000mm X 10000mm) Depth 18m-24m	Metre
4/07/04(e)	Labor for Well Sinking (Size 5000mm X 10000mm) Depth Above 24m	Metre
4/07/04(f)	Labor for Well Sinking (Size 4270mm X 7940mm) Depth 0m-6m	Metre
4/07/04(g)	Labor for Well Sinking (Size 4270mm X 7940mm) Depth 6m-12m	Metre
4/07/04(h)	Labor for Well Sinking (Size 4270mm X 7940mm) Depth 12m-18m	Metre
4/07/04(i)	Labor for Well Sinking (Size 4270mm X 7940mm) Depth 18m-24m	Metre
4/07/04(j)	Labor for Well Sinking (Size 4270mm X 7940mm) Depth Above 24m	Metre
04/07/05	Sand Filling	cum
04/07/06	High Steel Reinforcement Bars	Ton

4.8 STEEL SHEET PILES

4.8.1 Description

This specification outlines the method and resources involved in installation of sheet piling to facilitate works related to shore protection and excavation. Any alternate methods proposed by the contractor shall be at the discretion of Engineer and will have to be prior approved before commencement of work.

4.8.2 Materials

All materials and workmanship shall be in accordance with the AASHTO, Codes of Practice and other current specified standards at the date of tender except where the requirements of these Standards or Codes of Practice are in conflict with this Specification in which case the requirements of this Specification shall take precedence.

i) Source of Materials

The approved sources of supply of materials shall not be changed until the Contractor has confirmed that the materials from the new source can meet all the requirements of the Specifications. Materials failing to comply with the Specifications shall be removed promptly from the site.

ii) Standard Sheet Piles

Unless otherwise specified in the contract, all steel for sheet piles shall conform to ASTM A328/A328M, EN 10248-1, IS 2314:1986, BDS ISO 630, or equivalent standards approved by the Engineer. The steel shall be hot-rolled, with a minimum yield strength of 270 MPa (e.g., S275 or equivalent), and shall include corrosion protection (e.g., epoxy coatings or cathodic protection) suitable for sulfate-rich soils ($\geq 0.2\%$) and riverine conditions. The Contractor shall provide material test certificates verifying tensile strength, elongation, and chemical composition, as per the specified standard.

iii) Fabricated Sheet Piles and Storage

All fabricated piles, e.g., corners, junctions, box sections, and high modulus sections, shall be fabricated and supplied to the sheet pile manufacturer's recommendations for approval of the Engineer.

iv) Storage

The methodology of storage for Sheet piles shall have prior approval from the Engineer. If sheet piles of different grade steel are stored on site in corrosion preventive manner, and each pile shall be clearly marked as to its grade and piles of different grades shall be stored separately.

4.8.3 Construction Methods

The Contractor shall submit all Design, drawing and relevant details of the method of construction of the sheet pile wall and the plant and monitoring equipment he plans to adopt for approval of the Engineer. Details of bracing, struts to support piles also be provided.

i) Ground Condition

The Contractor shall report immediately to the Engineer any circumstances which indicate that in the Contractor's opinion, the ground conditions differ from the drawings, or which could have been inferred from the subsurface investigation reports.

ii) Program of Works for Sheet Piles

The Contractor shall submit to the Engineer each day the intended program of sheet pile wall construction for the following day and shall give 24 hours' notice of his intention to work outside normal hours and at weekends.

The Contractor shall ensure that during the course of the work, displacement or damage does not occur to the completed part of the work or any other elements that has already installed and has been accepted by the Engineer.

iii) Records

The Contractor shall keep records of sheet pile walls and shall submit two signed copies of these records to the Engineer not later than noon of the next working day after the element was installed.

Any unexpected driving conditions shall be noted in the records.

iv) Supervision and Control of the Works

The Contractor shall have experienced full-time site supervisor (s) at the site to be in charge for the sheet pile wall construction or installation.

The Contractor shall submit to the Engineer his quality plan one week prior to commencement of sheet pile work. Subsequent revisions, amendments or additions shall be submitted to the Engineer for approval prior to their implementation. Quality assurance and quality control documentation shall follow the Quality Assurance Plan of RHD.

v) Ordering of Piles

The Contractor shall ensure that the piles are available at the site for driving for incorporation in the Works. All piles and production facilities shall be made available for inspection at all time by the Engineer. Only new piles shall be used for permanent works. Piles shall be carefully examined

at the time of delivery. Damaged piles shall be removed from the site. The records of testing of the steel used in the piles shall be submitted to the Engineer for his approval prior to commencing the Works.

vi) Clutch Sealant

The Contractor shall apply a clutch sealant to the piles prior to pitching in accordance with the manufacturer's recommendations subject to the approval of the Engineer. Brief of clutch sealant or refer to other established document.

vii) Tolerances on Setting Out

Marker pins for the sheet pile wall positions shall be set out and installed by the Contractor. Prior to installation of the sheet pile wall, the element positions shall be checked by the Contractor and confirmed by the Engineer.

Table 1. Dimensional Tolerances for Steel Sheet Pile

S1. No.	Dimension to which Tolerance Applies	Tolerance
1	Width (a) Single piles b) Interlocked piles	$\pm 2\%$ $\pm 3\%$
2	Thickness of section	$\pm 5\%$
3	Weight	$\pm 5\%$
4	Length	± 50 mm
5	Squareness of cut for each section a) parallel to line of wall b) perpendicular to line of wall	$\leq 2\%$ ≤ 10 mm
6	Straightness	$\leq 2\%$ of pile length
7	Depth of Section	$\pm 4\%$

viii) Pile Handling and Driving

Pile Handling

When assembling piles before pitching the Contractor shall ensure that the interlocks are clean and free from distortion. All storage, handling, transporting and pitching of piles shall be carried out in such a way that no significant damage occurs to piles and their coatings.

Pile Installation

The Contractor shall satisfy himself that the sheet piles can be installed adequately to the correct depths through the reported or anticipated soil conditions. The Engineer shall be notified 24 hours

before the commencement of driving.

The piles shall be guided and held in position by temporary gates with each pile properly interlocked with its neighbor. Piles shall be interlocked properly according to the approved design. Where sheet piles are driven in panels, the end piles to each panel shall be driven in advance of the general run of piles. After allowing for initial penetration, no pile in the panel shall be driven to an excessive lead in comparison with the toe level of the panel in general and where hard driving is encountered this lead should not exceed 1 m.

At all stages during driving the free length of the sheet pile shall be adequately supported and restrained. The Contractor shall ensure that the sheet panels are driven without significant damage or declutching.

The selection of driving and contracting plant shall be made having due regard to the ground conditions and pile type. The sheet piles shall be driven to the specified level and/or resistance or if hard driving is experienced, to practical refusal (which shall be defined as when the rate of penetration is below 100 mm per minute when hammering continuously or 12 blows per 25 mm movement when using the appropriate equipment), or when visible damage to the pile occurs. Practical refusal for pile extraction shall be defined generally as when the rate of extraction of a pile is below 100 mm per minute when back-hammering or pulling (with equipment normally capable of withdrawing a pile) continuously (after an initial effort of 10 minutes). or when damage to the pile head occurs. If the piles have not penetrated to the levels specified, or have encountered obstructions, the Contractor shall submit details as to how he will overcome the problem.

Pile driving hammers shall be correctly positioned on the pile so that the hammer will be aligned as near to the axis of the pile as is practically possible. Freely suspended piling hammers shall be equipped with correctly adjusted leg guides and inserts. Where a hammer is mounted in a rigid leader, the leader shall be stable. The anvil block or driving plate shall be of sufficient size to cover as much as possible of the cross-section of pile.

Piles previously driven shall not be used until the Contractor can demonstrate that they can meet all the requirements of the Specification.

The Contractor may provide each pile in more than one length. Spliced joints shall be designed to cater for the combined effects of bearing, shear and bending stresses imposed upon the sheet piles. Splices shall be located to avoid maximum stress positions. If splices are to be welded, then these shall be designed in accordance with the guidelines given in AWS/BS 5135 or equivalent standard and the manufacturer's recommendations. Weld metal shall not encroach within the interlock areas so as not to interfere with the interlocking of the piles.

viii) Positional and Alignment Tolerance

Unless deflected by obstructions, sheet piles shall be installed within the following tolerances:

- in plan ± 75 mm of the given sheet pile line at commencing surface
- vertical 1 in 75
- level ± 50 mm of required top level.

Pile line dimensions shall be based on the nominal size of piles. Creep or shrinkage of the pile lines shall not exceed the manufacturer's rolling tolerances.

ix) Welding Standard

For manual metal arc and semi-automatic welding of carbon and carbon manganese steels, welding of piles and steel framework shall be carried out in accordance with AWS / BS 5135 or equivalent. Defective welds shall be cut out and replaced. Where steel piles are to be spliced by butt welding the interlocks shall not be welded unless a sealing weld is required.

x) Piling Records

The following records shall be kept and a copy shall be submitted to the Engineer:
Here is a well-structured table format for piling records:

S. No.	Record Parameter	Details/Notes
1	Pile Reference Number or Location	Unique identifier or location coordinates of the pile.
2	Pile Type and Grade of Steel	Specify the type (e.g., steel, concrete) and grade used.
3	Pile Length	Total length of the pile (in meters or feet).
4	Type of Hammer	Model and type of hammer used for driving (e.g., drop hammer, hydraulic hammer).
5	Date of Driving	Exact date the pile was driven.
6	Commencing Surface Level	Ground level at the start of the piling operation.
7	Depth Driven	Total depth the pile was driven into the ground.
8	Length of Offcuts	Length of discarded sections of the pile.
9	Length of Pile Extensions	Length of any extensions added to reach the required depth.
10	Driving Resistance	Driving resistance recorded at specific depths (e.g., blows per meter).
11	Interruptions/Unexpected Changes/Obstructions	Notes on issues faced, obstructions, and methods to resolve them.

This format can be filled for each pile and included in a piling report for submission to the Engineer. You may also consider adding a column for remarks or additional observations, if required.

4.8.4 Measurement and Payment

Steel sheet pile shall be measured in unit Metric Tonne. For installed piles directed to be cut off before reaching the penetration depth shown in the Drawing, the portion cut off will not be measured. The temporary sheet piles shall be considered as the property of the Contractor.

Payment for Steel Sheet Pile shall cover all costs of supplying, furnishing, handling, storing and

installing piles including placing, driving, cutting holes and other materials and incidental works as per the Specifications. No additional payment shall be made for bracing, struts provided, if any, to support the sheet piles.

Pay Item shall be:

Pay Item No.	Description	Unit Measurement
04/08/01	Setting Sheet Piles	Tonne
04/08/02	Setting Sheet Piles (Re-used)	Tonne
04/08/03	Setting Sheet Piles (Permanent)	Tonne
04/08/04	Setting Sheet Piles (Re-used) (Permanent)	Tonne

4.9 RE /MSE Wall

4.9.1 Description

The specification covers construction of reinforced soil structures together with the construction of earthwork in layers, assembly and placing of reinforcing elements and fascia elements during the construction process and all associated works. Any alternate methods proposed by the contractor shall be at the discretion of Engineer and will have to be prior approved before commencement of work.

The work shall include the design and construction of the reinforced soil structure and ground improvement measures required, if any.

The reinforced soil retaining structures can be used as, (i) Reinforced soil retaining wall, (ii) Reinforced soil abutment, (iii) Reinforced soil slope

Reinforced soil structures with a slope face angle steeper than 70° are categorized as reinforced soil walls, and those with a slope face angle less than 70° are considered as reinforced soil slopes. The detailed design and drawings of the work shall be done in accordance with the BS: 8006:2010 “Strengthened/Reinforced Soils and Other Fills” or equivalent. The earthquake loads as per BNBC latest edition. Proprietary specifications shall be incorporated wherever relevant.

The Contractor shall determine the allowable bearing pressures and the maximum settlement of the foundation material under the RE wall using information obtained from the site-specific geotechnical investigation.

Subsurface drainage which complies with the specification shall be provided within the RE where necessary to intercept groundwater and to prevent the development of hydrostatic pressure behind the facing panels. A separate drainage system which complies with the specification shall be provided to collect and discharge surface water into the storm water drainage system. The specific

checks for the strength and service limit states required for RE wall design are listed below:

Strength Limit States for RE walls

External Stability

- Limiting Eccentricity
- Sliding
- Bearing Resistance

Internal Stability

- Tensile Resistance of Reinforcement
- Pullout Resistance of Reinforcement
- Structural Resistance of Face Elements
- Structural Resistance of Face Element Connections

Service Limit States for RE walls

External Stability

- Vertical wall movements
- Lateral wall Movements

Global Stability of RE walls

- Overall Stability
- Compound Stability

In cases where specific design details for the RE wall are not provided for a particular project, the Contractor may refer to the following guidelines. However, it's important to note that any action taken by the Engineer, including approvals, checks, certificates, consents, examinations, inspections, instructions, notices, proposals, requests, tests, or any similar acts, or the absence of disapproval, shall not exempt the Contractor from their contractual responsibilities. This includes responsibilities related to errors, omissions, discrepancies, and non-compliance with the contract terms. The Contractor shall have in place a quality management System, which ensures compliance with the performance requirements described on the drawings and in the Specification.

4.9.2 Material

(i) Reinforcing Elements

The reinforcing element shall be metallic in the form of ties (galvanized steel bars/tendons) or mats of metal (steel grids, woven and welded steel wire meshes) or synthetic (PET, HDPE, PVA, PP) reinforcement in the form of grid or strip or strap or combination of metallic or synthetic or any other proprietary material which shall be approved by the Engineer and shown on the drawings.

In case of synthetic reinforcements, there shall not be any steel component in the connection system, neither encased nor coated inside the connector, contributing to connection strength. A friction-based connection system shall not be allowed.

Carbon steel ties shall comply with BS EN 10025 / IS: 2062 or any other equivalent standard and

have a silicon content of not more than 0.55 percent. The fabricated element shall be galvanized in accordance with IS 4759 and IS 2629 or any other equivalent standard, and the minimum zinc coating weight shall not be less than 1000gm/sq.m

The steel ties with minimum bearing and shear strength of 490N/mm² shall comply with the requirements of BS EN 10025, Grade S 355 JR, or IS: 2062 grade Fe 490 or any other equivalent standard except for the elongation (on base metal) for which minimum 22% is acceptable.

The panel lugs shall be manufactured from hot-rolled steel ties with the same steel quality and grades as specified above, except that the minimum zinc coating weight not less than 600 gm/sq.m.

All permanent metallic connectors (exposed to soil), tie strips, and lugs shall be hot dip galvanized. Nuts/ bolts (fasteners) shall be galvanized as per requirements of IS: 1367-Part 3. Nuts/ bolts (fasteners) shall be grade 10.9 or any other equivalent standards.

For all metallic components, where holes or penetrations are made through the reinforcing elements to accommodate connections such as bolts, pins, or other, the cross-section thickness and/or width of metallic component shall be increased to account for section loss caused by the hole or penetration. The manufacturer of geogrids, geotextiles, geostrips, polymeric strips or straps, polymeric ties or any other geosynthetic material, including any proprietary geosynthetic material, for use as reinforcing element shall fulfill the following requirements:

- Shall have ISO (ISO-9001), (ISO-45001) and (ISO-14001) /CE Certification/ EPD Certifications or any other equivalent certification for manufacturing process and quality control,
- The product shall have certification for use as soil reinforcing material from an agency accredited for certifying geosynthetic reinforcement products.
- The manufacturer shall provide test reports from an independent laboratory with valid accreditation, for all the tests needed to establish all the reduction factors listed below
 - RF_{CR} - Reduction factor for creep.
 - RF_{ID} - Reduction factor for installation damage
 - RF_W - Reduction factor for weathering
 - RF_{CH} - Reduction factor for chemical/ environmental effects.
 - f_s - Factor for the extrapolation of data

All the above factors shall be determined in accordance with the provisions of ISO/TR 20432-“Guide to the determination of long-term strength of geosynthetics for soil reinforcement. Or, any other equivalent standard.

(ii) Earth Fill and Environmental Conditions

The fill in the reinforced soil zone shall have drained or effective angle of friction not less than 30°, measured in accordance with BS 8006:2010 or IS: 2720 (Part 13) or equivalent, by conducting a drained direct shear test. In case the fill material has 25 percent or more particles of 4.75 mm or

larger, drained shear test using large shear box may be conducted (IS: 2720: Part 39: Section 1 or equivalent) . The gradation of fill soil shall be as per following limits.

Sieve Size	Percentage passing
75mm	100%
425 micron	0-60%
75 micron	less than 15

Materials with more than 15 percent passing 75 micron sieve, but less than 10 percent of particles smaller than 15 microns are acceptable provided PI is less than 6 and angle of friction is not less than 30°.

The fill material used in the reinforced soil zone shall be free from organic or other deleterious materials and shall not react adversely (chemically, electrically or biologically) with the reinforcement material and / or facing material.

Properties of fill soil in the reinforced zone, unreinforced zone (or retained/back fill) soil and the foundation soil shall be determined accurately during the construction phase, as per quality assurance plans and directions of Engineer so as to ensure that these are the same as those considered in the design phase.

The fill soil in the unreinforced zone shall conform to the requirements specified in the design.

Where galvanized steel reinforcement is used, the fill material shall be free draining granular material and shall meet the following requirements as per table below

Table 2. Recommended Limits of Electrochemical Properties for Reinforced Fills with Steel Reinforcement

Property	Criteria	Test Method
Resistivity	> 3000 ohm-cm	AASHTO T-288 or equivalent
pH	> 5 and < 10	AASHTO T-289 or equivalent
Chlorides	< 100 PPM	ASTM D 4327 or equivalent
Sulphates	< 200 PPM	ASTM D 4327 or equivalent

(iii) Facing Material

The facing system shall be one of the following

- Precast reinforced concrete panels
- Precast concrete blocks and precast concrete hollow blocks.
- Gabion facing

- Wrap around facing using geosynthetics
- Metallic facing, prefabricated in different shapes including welded wire grid and woven steel wire mesh
- Other proprietary and proven systems

Facing shall be sufficiently flexible to withstand any deformation of the fill and foundations. The facia units to be adopted in the project shall be shown in the drawings and shall be approved by the Engineer.

Facia type adopted shall be given in the design and shown with complete details in the drawings. The system supplier shall provide any test data to satisfy the Engineer regarding the properties and suitability of the facia system adopted, if so required.

Where facia such as wrap around or mechanically woven gabion or welded wire and woven steel wire mesh facings have been used and where climate conditions are appropriate, a green finish shall be provided where specified.

Connection between the facia panels and the reinforcing element shall be by using either nut or bolt, HDPE inserts with bodkin joint, hollow embedded devices, polymeric/ steel strips/rods/pipes, fibre glass dowels or any other material shown in the drawings. Connection relying on steel bar should be avoided as the steel bar may get corroded and impact the durability of the structure. Connection between facia panel and reinforcing element shall not rely only on concrete strength and must have direct load sharing by steel reinforcing bar. Hollow sleeves where reinforcement is passed and relying on only on concrete strength shall not be permitted. The connection between the panel and the reinforcement shall provide for 100 % of the long-term design strength of the reinforcing element in continuity.

In case of modular block facia and other type of facia such as gabion facia, where the reinforcement is held by friction between the facia block and the reinforcement, the results of pullout test as per ASTM D 6638 “Standard Method of Test for Determining Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units” shall prevail. The hollow concrete blocks must have mechanical connection and friction-based connection shall not be allowed.

The available connection strength shall satisfy the design requirements and shall not be less than the maximum possible tensile force that the reinforcement layer under consideration may be subjected to. Connection test report shall be submitted prior to construction.

The connection strength shall be derived based on third party test conducted on all types of facing panels (as per the proposed shape). The third-party test reports shall be produced for all types of

connections. No other mechanical connection system where the connection strength cannot be justified by laboratory testing shall be allowed.

The connection test methodology shall be as follows:

The design connection strength values shall be established based on connection pullout test results. To estimate the realistic panel connection strength values, the field pullout testing on the actual panels shall be tested. The connection strength testing method shall be carried out on a horizontal bed. The test panel can be placed in an open pit excavated below ground level or beam arrangement on a level ground to accommodate soil cover over the panel. The sand is placed layer by layer and compacted to the required thickness.



Fig 4.9-1 Typical Panel Connection Testing Setup

The steel loading frame is placed over the compacted fill at the centroid of the connectors symmetrically. The hydraulic jacks and the associated accessories should be assembled as shown in Figure above. The load is applied gradually till the failure.

4.9.3 Construction Methods

(i) Depth of Foundation

A strip footing, minimum 350mm wide and 150mm thick in 15Mpa grade plain concrete, shall be provided at founding level to receive the fascia or the bottom most reinforcement.

The depth of embedment below the outer finished road level at the foot of the wall shall not be less than 500 mm or as per site condition subject to the design. In case rock is met above founding level, the depth of embedment shall be adjusted as per ground conditions.

(ii) Concrete Quality and Strength

Panels shall be made of vibrated concrete with the following requirements:

Characteristic compressive strength at 28 days	Minimum 30 MPa
Maximum aggregate size	20 mm
Maximum free water/cement ratio	0.45

For sea walls or structures facing severe exposure conditions, thicker panels with higher cement (Sulphate resistant cement) content shall be specifically designed for the intended purpose. Reinforcing element should be polyvinyl alcohol (PVA) coated synthetic strips.

(iii) Laying of Reinforcement

The reinforcing elements shall be placed at right angles to the face of the wall or design axis, with greater cross-sectional dimension in the horizontal plane and the length shall be as shown in the drawings. Reinforcing elements such as geogrids, shall be stretched and held taut by driving nails or pegs at the farther end. Reinforcing element as such as geostrips shall be laid in V shape fashion from face to rear end and shall be anchored with steel hooks. Without steel hooks the polymeric reinforcement shall not be allowed.

Add for steel tendon

(iv) Facing Batter

It may be necessary to set facing unit at an additional batter than as provided in the drawings since there is a tendency for initially positioned units of facia to lean outward as the fill material is placed and compacted. Care and caution shall be taken to accommodate this phenomenon. At the end of the construction, the face may have a slight residual inward batter.

(v) Drainage

Drainage bay shall be provided. The width of the drainage bay shall be 600 mm behind the facing element. The drainage material shall conform to the specifications of the filter media as outlined below:

- Filter design may not be required if embankment consists of CH or CL soils with liquid limit greater than 30, resistant to surface erosion. In this case, if a layer of material is used as bedding for pitching, it shall be well graded, and its D 85 size shall be at least twice the maximum void size in pitching
- In the foregoing, D 15 means the size of that sieve which allows 15 percent by weight of the filter material to pass through it and similar is the meaning of D 50 and D 85 (15 being replaced with 50 and 85 respectively).
- If more than one filter layer is required, the same requirement as above shall be followed for each layer. The finer filter shall be considered as base material for selection of coarser filter.
- The filter shall be compacted to a firm condition. The thickness of filter is generally of the order of 200 mm to 300 mm. Where filter is provided in two layers, thickness of each layer

shall be 150 mm

Alternatively, the multilinear geo-composite drain of specifications mentioned as per Clause of RHD specifications (2.14.9) shall be adopted.

(vi) Laying and Compaction

The reinforcing elements shall be laid free from all kinks, damage and displacement during placing, spreading, leveling and compaction of the fill. The programme of filling shall be such that no construction plant moves directly on the reinforcement.

All construction plant having a mass exceeding 1500 kg shall be kept at least 2.0m away from the face of slope or wall.

In the area up to 2.0 m from the face of slope or wall, the following compaction plant shall be used:

- Vibratory roller having a weight per meter width not exceeding 1300 kg with total weight not exceeding 1500 kg
- Vibratory plate compactor of maximum weight 1000 kg
- Vibro tamper having a weight not exceeding 75 kg

Before allowing the movement of vehicles over the reinforcement, a minimum compacted thickness of 150mm or as per field condition, shall be provided over the reinforcement and the speed of the vehicles shall be restricted to 10 km/hr.

During construction of reinforced fill, the retained material beyond the reinforcement at the rear of the structure shall be maintained at the same level as reinforced fill.

Fill shall not be placed on surface that contains mud, organic soil or area that have not met compaction requirement.

The thickness of compacted layer shall not be more than 200 mm, compacted to at least 95 per cent of maximum laboratory density.

(vi) Construction Serviceability and Tolerances

The construction tolerances shall be as per the following:

Casting of pre-cast RCC panels: All elements shall be manufactured within the following tolerances:

- All dimensions within ± 5 mm
- Evenness of the front face: ± 5 mm over 1500mm
- Difference between lengths of two diagonals: 5mm max.
- Thickness: + 5 mm (-) 0 mm

Description	Tolerance
Location of plane of structure	± 50 mm – metallic reinforcement ± 75 mm – synthetic reinforcement
Bulging (Vertical) and Bowing (Horizontal)	± 20 mm in 4.5 m template (Metallic) ± 30 mm in 4.5 m template (Synthetic)
Steps at joints	± 10 mm

Dimensions of modular concrete blocks shall not differ more than ± 2.5 mm for length and width and ± 1.5 mm in height.

Minimum vertical movement capacities required for facing systems to cope with vertical internal settlement of reinforced fill shall be as below:

Structural form	Minimum vertical movement capacity of system	Differential settlement from EN 14475 or equivalent	Alignment from EN 14475 or equivalent
Discrete panels	Joint closure of 1 in 150 relative to panel height	~ 1% with panel aspect ratio ≈ 1 to ~ 0,5% with larger ratios.	± 25mm
Full height panels	Vertical movement capacity of connections 1 in 150 relative to panel height	$\leq 0.5\%$	± 25mm
Concrete blocks		~ 0.5%	± 50mm
Semi-elliptical facings	Vertical distortion of 1 in 150 relative to panel height	~ 2%	± 100mm
Geotextile/Geogrid wrap-around facings	No specific limit except for appearance or serviceability considerations	~ 2%	± 100mm

Gabion facings	No specific limit except for appearance or serviceability considerations	~ 2%	± 100mm

4.9.4 Measurement and Payment

The unit of measurement for furnishing and fabricating the materials for the RE walls, including concrete facing panels, leveling pad, soil reinforcements, attachment devices, fasteners, bearing pad blocks and shims, supply and installation of specified drainage bay/ multilinear geo-composite material, joint materials and incidentals shall be the square meter of wall surface area. The wall surface area shall include the surface area of nominal panel joint openings and wall penetrations such as pipes and other utilities. The quantity to be paid for shall be measured on the basis of wall surface area supplied including all associated cost.

The rate shall include full compensation for the design and drawing of the RE wall.

The rate shall exclude the cost of investigations, design and construction of ground improvement measures.

Measurement for friction slab and crash barrier shall be separately and in linear meter.

Pay Item shall be:

Pay Item No.	Description	Unit Measurement
04/09/01	Reinforced Earth Wall	sqm
04/09/02	Supply and laying of Reinforced Earth fill at the reinforced zone as per drawing and specifications.	Cum
04/09/03	Supply and laying of Embankment fill at the unreinforced zone as per drawing and specifications.	Cum
04/09/04	Excavation up to the depth of the embedment.	Cum

4.10 PRE-CAST SPUN PILES

4.10.1 Description

This specification for driven of spun piles generally describes the method used for the installation of driven precast with various size diameter of spun piles ranging from Grade 60MPa – 120 MPa.

This specification describes the procedures of driven piles, penetration, or set that is required within the given scope of works. Any alternate methods proposed by the contractor shall be within stipulated cost and at the discretion of Engineer and will have to be prior approved before commencement of work.

The design, materials and workmanship of the precast pretensioned spun concrete piles shall comply with the relevant clauses of BS 8004 :1986, BS 8110 : 1997, JIS A 5337 :1993 or equivalent standard and is to be read in conjunction with the condition of contract and drawings.¹

4.10.2 Materials

The materials used in the manufacture of the precast prestressed spun piles shall comply with the following specifications or requirements:

- a. Cements — The cement shall be ordinary Portland Cement and shall comply with MS 522 or equivalent standards.
- b. Steel Reinforcements — Steel reinforcement shall comply with the following specifications:
 - (1) Rolled steel bars and hard-drawn steel wire shall comply with MS 144, MS 146 or equivalent standards
 - (2) Prestressing steel shall comply with JIS C3109 or BS 4486 and BS 5896 or equivalent.
- c. Aggregates — Aggregates shall be clean, durable and comply with MS 29 or equivalent. Maximum size of aggregate shall be 20mm.
- d. Water — Water shall be free from harmful amount of matter injurious to concrete and its reinforcement and shall comply with MS 28 or equivalent
- e. Admixture — Admixture shall comply with MS 922 or equivalent. Calcium chloride shall not be used.
- f. Test certificates for cement, reinforcement and admixture from approved laboratory shall be available for inspection by the Employer's Representative.

4.10.3 Construction Method

i) Equipment and resources

The contractor shall ensure appropriate piling rig, hydraulic hammer, mobile crane, welding sets are used based on prior approval of the Engineer before commencement of work.

ii) Setting Out

Pile setting out shall be carried out jointly with the site engineer, and shall include any additional reference points necessary, to enable immediate checking and cross-referencing for any problematic pile positioning.

iii) Piling Platform

Pier pile positions shall be installed over a suitable pile installation platform, whether they be on firm ground or on an elevated staging. Any platform/staging established shall be robust and stable enough to handle weights of piling machine, additional cranes as necessary and the working forces that will develop during pile driving. The platform must be of known elevation to enable the control of pile penetration and/or pile setting when necessary.

iv) Pile Driving Termination Criteria

1. Pile set shall be decided through a test pile installation.
2. If pile set is the criteria, the required working load shall be agreed, and stoppage of pile driving shall be based on Hiley's pile driving formula. The graphical "set over 10-blow readings" shall be obtained. Subsequent calculation using agreed driving parameters shall determine adequacy of driving.

Hiley formula:

$$SET = \frac{AWh}{fL} \times \frac{(W + Pe^2)}{(W + P)} - \frac{C}{2}$$

Hammer Efficiency	A
Mass of Hammer	W
Drop of Hammer	h
Safety Factor	f
Pile Working Load	L
Total Mass	P
Coefficient of Restitution	e
Temporary Compression	C

3. The actual set values will be recomputed at site based on the variable parameters of actual pile length installed and the actual temporary compression recorded. If pile penetration is the

criteria, the outcome of the test pile installation shall be a guide to the required depth of penetration.

v) Pile installation

Piles shall be lifted from its stacked position utilizing its two designated lifting points. Canvass padded slings shall be used for spun piles.

The toe end of the starter piles shall be pitched/planted to its exact position manually by suspending the pile from its driven end.

With the toe position fixed, the required pile inclination shall then be adjusted to the required angle while the guide rails and required back supports are firmly secured.

Counter checks shall be made through two survey stations, preferably at right angles to each other, to confirm the position at the pile base and inclination of pile shaft. The stations should be situated at least 30m away.

Pile driving shall utilise the most suitable hammer for driving the type of pile to the set without damage to the pile head. The type (static, vibration or dynamic), weight and mechanism (diesel, hydraulic etc.) of the hammer shall be approved by the engineer.

When driving commence, the first few blows and meter of penetration shall be closely monitored to enable any initial deviation to be physically corrected.

Large deviations in terms of position and inclination (in excess of specified tolerances) shall merit an extraction and re-drive at this stage if forcible corrections are not adequate.

For deviations that inevitably occur at deeper penetrations, only measurements in the final set position shall dictate, amongst other factors, the pile acceptance or otherwise.

Where driving depths go below the piling rig's base level, a suitable dolly or temporary pile extension of known length and material properties shall be used to enable proper computation of the pile set.

vi) Pile Driving Records

Pile driving shall be recorded through an agreed format and shall detail all the relevant information including times for driving and jointing.

The records shall be comprehensive to discount any uncertainty or reservations as to the piles' integrity to be part of the permanent structure.

Pile Driving Record				File Code Ref:			
Work Item			Location				
Pile No.			Hammer Type				
Driving Date			Hammer Weight	(striking or impact part)	kg		
Start Time			Drop Height	cm			
Finish Time			Striking Energy	Kg.m			
RC Pile Size	cm	Length	m	Casting			
Extension Pile Size	cm	Length	m	Casting Date			
Connection Box		Welding	m	Weld Thickness	mm		
Pile Driving Results							
No. of blows	Penetration (cm)	Drop Height (cm)	Pile Tip Depth (m)	No. of blows	Penetration (cm)	Drop Height (cm)	Pile Tip Depth (m)
			Design		Actual		
Elevation of pile Tip (pile nose) (m)							
Elevation of bottom of pile cap (m)							
Pile Length (m)							
Final Refusal (cm)							
Transverse Tolerance (Y axis)							
Longitudinal Tolerance (X axis)							

Other Remarks:		
For Subcontractor:	For Engineer:	For Client's Representative

vii) Pile Jointing and Splicing

Piles shall be joined at the specified position using the recommended method or propriety systems as required.

The required setting and hardening times for primers and epoxies, where used, shall be adhered to when pile joints are made, to ensure a safe and effective joint.

When welding joints, no gaps shall be allowed and full bearing at the connecting plates between the driven and the extended length shall be ensured. Pile driving will then be resumed after the required setting/hardening times for the weld to develop its strength.

viii) Pile Cut-Off

Piles shall only be cut-off after securing the directive and acceptance by the engineer in charge. This is to ensure that any re-driving work that would be required can still be carried out when such situations warrant.

The value for pile cut-off level must be formally agreed and any piles that need to be 'brought up' to the required cut-off level must meet the contractual agreement and specification guidelines.

Where pile cut-off levels are below ground, excavation sides shall either be sloped or protected by an earth retaining structure to prevent collapse of the excavated pit.

Where pile cut-off levels are below water level, suitable enclosing structures (e.g. cofferdams) shall be installed to exclude water from the works.

ix) Fabrication of Pile Plug

Stripping of piles and fabrication of pile heads for concrete piles shall be carried out in accordance to the Drawings. The lengths of stripping and reinforcement to be provided shall be adequate to anchor the pile into the pile cap to be constructed.

4.10.4 Measurement and Payment

Payment shall be made for for all costs incurred related to testing including, but not limited to procurement, preparation and installation, conductions of the tests, and subsequent reporting of the results.

Pay Item No.	Description	Unit Measurement
04/10/01	Installation of Pre-stressed Concrete Spun Piles of specified material strength and diameter	m

4.11 STEEL SCREW PILES

4.11.1 Description

This specification consists of materials, equipment, fabrication, testing, and construction of Screwed Steel Pile in accordance with relevant standards, drawings, or as directed by the Engineer. Any alternate methods proposed by the contractor shall be within stipulated cost and at the discretion of Engineer and will have to be prior approved before commencement of work.¹

4.11.2 Material

Steel pipe piles used for Screw Steel Piles shall conform to the requirements of JIS A 5525, ASTM A252, ASTM 53, EN10217, EN10219, BS, or equivalent standards.

Physical-mechanical properties of steel material for steel pipe pile

Grade	Yield Point (N/mm ²)	Tensile strength (N/mm ²)	Elongation (%)
SKK400/ ASTM 1006 or equivalent	235 or more	400 or more	18 or more
SKK490/ASTM 1006 or equivalent	315 or more	490 or more	18 or more

Steel for the blade of the pile tip shall conform to the requirements of ASTM A572 / JIS G 3106, Physical-mechanical properties of steel material for the blade of pile tip:

Grade	Yield Point (N/mm ²)	Tensile strength (N/mm ²)	Elongation (%)
(16mm < t ≤ 40mm)	315 or more	490 - 610	21 or more (Testing specimen type 1A)
(40mm < t ≤ 75mm)	295 or more	490 - 610	23 or more (1) (Test specimen type 4)
(75mm < t ≤ 100mm)	295 or more	490 - 610	23 or more (Test specimen type 4)

Note(1):

In the case, if testing specimen type 1A is used for more than 40mm and less than 50mm, elongation 21% or more shall be applied.

- (a) The pile tip blade shall be selected from among certified blade.
- (b) The welding of pile tip blade and steel pipe pile shall follow JIS A 5525, ASTM A252, ASTM 53, EN10217, EN10219, BS, or any other equivalent standard and adopt full penetration welding method.
- (c) The Contractor shall submit to the Engineer for approval of steel certificate from the Manufacture (test results of physical-mechanical properties of the steel) for fabrication of steel pipe, Quality Control Program, method of manufacturing including welding detail of joint of piles, quality testing of welding, and experience of manufacturing, supplying steel pipe piles.

4.11.3 Construction Method

The Contractor shall submit all relevant details of the method of construction of the steel screw pile wall and the plant and monitoring equipment he plans to adopt for approval of the Engineer.

i) General

- a. Piling of Rotation steel piles shall be executed in the presence of the Engineer or his representative. All piling shall be carefully located on the lines and spacing as indicated in the Drawings and shall be installed vertically.
- b. The piling of Screw Steel Piles shall be executed by using the dedicated casing rotation machine. The contractor shall take full responsibility in selecting capable rotation machine to ensure proper construction and schedule of the project. The operator of the casing rotation machine shall be properly trained and have experience of operating the machine. Rotating force shall be applied from the casing rotation machine to a Screw Steel Pile by gripping the pile body directory through the collar with high-strength serrate plate.
- c. If piles hit any obstructions or encounter difficulty to penetrate hard soil before

reaching proper bearing layer expected from the nearest soil investigation data, the Contractor shall report the situation to the Engineer without delay and remove the obstructions with approval by the Engineer.

- d. The soil condition shall be foreseen by the Contractor. In case of difficulty to remove the obstructions, the pile shall be rotated in reverse to pull it out. Then an auxiliary method can be used to remove the obstructions. Auxiliary methods include pre-boring by the earth-auger method, casing excavation using a casing rotator with hammer grab, or excavating inside soil of the Screw Steel Pile with a hammer grab and no additional payment will be made for it.
- e. The Contractor shall report immediately to the Engineer any circumstances which indicate that in the Contractor's opinion the ground conditions differ from the drawings, or which could have been inferred from the subsurface investigation reports.

ii) Daily Record

On completion of installation of each Screw Steel Pile the Contractor shall submit daily records to the Engineer within 24 hours giving the information listed in Table below.

General Record	Installation of Rotation Steel Pile
- Date - Weather condition - Working group (organization, personnel) - Equipment and machineries - Detail of working time - Progress report - Safety report	- Foundation No. - Pile identify number, coordinates for determining location of the pile - Natural ground level - Soil condition - Pile head elevation. - Pile tip elevation. - Construction equipment - Detail of acceptance of steel pipe, pile tip - Detail of joint welding (position, time and conditions) - Construction time - Detail of any obstacles - Auxiliary method if used (Hammer grab, others) - Fully record of rotating force, rotating torque, weight of counterweight to each meter in depth - others

iii) Trouble and Failure Report

If the Contractor causes any damage to utilities or adjacent structures during the works, the Contractor shall submit the report of the damage without delay with the proposed plan for the repair and improvement to avoid repetition of such damages to the Engineer.

iv) Storage and Handling

- a) The units of Screw Steel Pile shall be stored above the ground by timber supports placed on firm ground, which is not liable to subside, whether wet or dry, under the weight of the units. Where the units are stacked in layers, they shall not be stacked more than three (3) layers high, with timber supports placed between each layer. Supports for each layer shall be placed on those of the preceding layer and shall be placed not more than 20 % of the length of the unit from each end.
- b) The Contractor shall attach hanging hooks to the Screw Steel Pile segments to allow vertical lifting of the segments. A minimum of two (2) hanging hooks are required for vertical lifting. The method of attachment shall not cause damage to the Screw Steel Pile segment during attachment, lifting of the segment, and removal of attachment. The method of attachment and location of the attachment points shall be included in the method statement. Only the approved hanging hooks shall be used during lifting, and Screw Steel Piles shall be stored and transported not to damage these hanging hooks. Piles damaged during handling shall be replaced at the Contractor's own expense.

iv) Monitoring of Operation

During the execution of the Screw Steel Pile, working torque, penetration rate, and vertical load shall be monitored for all the piling works to evaluate the correlation of sub-ground soil condition and working torque. The monitored record of Screw Steel Pile shall be submitted to the Engineer within 48 hours after completion of all Screw Steel piles for each foundation.

v) Finish Piling Operation

- a) The Contractor shall request the approval of the Engineer when the Contractor finishes the piling works.
- b) Working torque and other measured data shall be used to confirm that the pile tip has reached the bearing layer. To stop piling operation, the following conditions shall be satisfied.
 - The pile tip has reached the design elevation.
 - Measured data has suggested that the pile has reached the bearing layer.
 - Necessary penetration depth to the bearing layer (in principle, 1.0 diameter of pile or more) has been confirmed.
- c) If required penetration has not been obtained due to an extremely hard bearing layer, the Contractor shall finish the piling subject to the approval of the Engineer.
- d) In this case, top of Screw Steel Upper Pile shall be cut off by oxyacetylene cutting or other adequate method at the elevation approved by the Engineer.
- e) Following information shall be documented and submitted to the Engineer.
 - Foundation number and pile number.
 - Pile specification (diameter, thickness, length etc.);
 - Record of completion situation (finishing working torque, elevation of the bearing

layer, penetration length into the bearing layer, etc.);

vi) Tolerance

Tolerance of Screw Steel Pile shall comply with “Quality Control Standard of Steel Pile Foundation” by Ministry of Land, Infrastructure, Transport and Tourism. Detail of tolerance of completed pile shall be given in the Table below.

Item	Tolerance
- Position of pile center	- $D_p/4$ or less and $\pm 100\text{mm}$
- Elevation of Pile top	- $\pm 50\text{ mm}$
- Inclination of pile	- $1/100$ or less
- Penetration length into the bearing layer	- $1.0 D_p$ or more

Note: D_p = Diameter of pile

vii) Site Welding Work

- a) The joint of Screw Steel Piles shall be welded in complete penetration butt weld with suitable mild steel backing ring plates provided. Site welding method shall be semi-automatic arc weld or other weld method approved by the Engineer. The ends of the sections shall be suitably prepared for welding. The welding procedures shall comply with all requirements of the following welding specifications. The bead for temporary welding shall be longer than 80mm at more than six locations (Outside pile diameter from 700mm to 1000mm) in one ring welding line.
- b) When the segments are welded together, the seam of one segment shall be located at a distance of more than one-eighth of the segment circumference from the seam of another.
- c) The Contractor shall assign the qualified welding engineer for quality control, who has experience the site welding of steel pipe and shall be responsible for all of welding works. The Contractor shall submit his qualifications for the Engineer's approval.
- d) Welders hired for this purpose shall be successful passers of examination necessary for site welding of piles or other licensing examinations equivalent or superior to it as provided in AWS D1.1, JIS Z 3801, JIS Z 3841, WES 8106 or equivalent and have already been engaged in welding operations for six (6) month or longer.
- e) The joints of the Screw Steel Pile shall be welded in accordance with AWS D1.1 or equivalent
- f) For welding the Screw Steel Pile at the site, the following information shall be documented and reported to the Engineer.
 - Pile number and position of the welding area;
 - Welding data, weather conditions including temperature, rain and wind condition;
 - Name of welder;
 - Method of welding (posture, voltage, current, type of electrode, etc.);
 - Time record for welding.
- g) Tolerance of the assemblage of components shall be in accordance with the followings.

- Root opening shall be from 1 mm to 4 mm
- Dislocation between joining piles shall be 3 mm (Outside pile diameter from 700mm to 1000mm) or under in accordance with relevant ASTM / JIS standards
- h) Cleaning and drying of the welding line in both components prior to welding.
 - There shall be no black skin, rust, paint or grease present at the welding area
 - Welding line shall be thoroughly dried
- i) Attachment and removal of hanging hooks, etc.
 - Welding of parts such as hanging hooks for lifting shall be carried out in the shop. If site welding is unavoidable, the welding shall be conducted under adequate control.
 - Removal of temporary parts such as hanging hooks from the piles shall be performed by oxy-acetylene cutting or other adequate method with great care to prevent damage to the base metal of the piles.

viii) Inspection for the site Welding Work

- a) The inspection of site welding shall be carried out by using ultrasonic test method throughout with frequency 1 per about 20 welding joints probing from 4 directions, 30 cm circumferential length per direction. However, if necessary, the Engineer can request more ultrasonic test to verify welding quality.
- b) There shall be no cracks appearing in or near the weld beads. The inspection shall be carried out by visually.
- c) Butt welding joints shall be free of weld pits on the bead surface. There shall be no height difference exceeding 5 mm. The depth of undercut shall not exceed 0.3 mm. There shall be no overlap.

In order to verify the capacity of Screw Steel Piles, specified number of static tests shall be carried out on pilot piles in accordance with the instruction of the Engineer.

4.11.4 Measurement and Payment

Payment shall be made for design, installation and completion of screwed steel piles including all associated costs to carry the designated working loads including the pile cap weight and also satisfying the load test criteria all as per design.

Pay Item No.	Description	Unit Measurement
04/11/1	Supplying, handling, transporting, pitching and driving piles	Liner meter

4.12 PARALLEL SEISMIC TEST

4.12.1 Description

This work shall consist in performing parallel seismic logging of deep foundation in conformance

with ASTM D8381/D8381M-21 or equivalent standard as approved by the Engineer. Any alternate test methods proposed by the contractor shall be within stipulated cost and at the discretion of Engineer and will have to be prior approved before commencement of work.

4.12.2 Equipment

In the PS method, the receiver response must be recorded. The equipment needed to perform the data collection includes the following:

1. Digital signal analyzer (or PC-based data acquisition) system with at least two channels with at least 4096 data points per channel.
2. Instrumented impulse hammers weighing 1.4–5.5 kg to impart and measure the impact force. This signal is also used to trigger the data acquisition on impact.
3. Hydrophone receivers are required for borehole-based PS tests

4.12.3 Construction

In order to conduct the test, a vertical plastic tube is installed into a hole in the ground. The tube should be parallel to the Pile or Pier or Foundation Element to be tested. The horizontal distance between the tube and foundation element should not exceed 0.5m. The diameter of the tube should not be less than 40 mm and it should be installed up to the depth which is 3 m greater than the expected lowest level of the foundation element under consideration. When the tube is installed in dry soil, the annular space between the tube and the hole is filled with cement grout from top to bottom of the tube.

At the beginning of the test, the plastic tube is filled with clear water, ~~because~~ to lower down hydrophone in lowered down the tube to capture P-waves (Compressional Wave). The tube is capped at the top and bottom to avoid ingress of debris and any leakage of water from the tube until the test is completed.

The hydrophone is sensitive to audio frequencies and it is kept at every 0.5m depth (from EGL) to receive P-wave data, as the hammer hits the nearby structural component supported by the foundation being tested. The depth of the hydrophone, placed at different depths inside the tube, is obtained by the depth meter. The test is carried out from the top to bottom of the tube.

At each depth, the top of the foundation element or an appropriate spot on the superstructure is hit with the hammer. The location of the hammer striking point is kept constant all through the test. The hammer stroke creates longitudinal waves that travel down the foundation element and then through the soil, and the hydrophone (placed inside the tube) receives the P-wave travelling through the soil. The waves that arrive at the hydrophone are transmitted to the PSI and recorded in the computer which is connected to it. Upon completion of the test, a profile of P-wave forms with depth is obtained by compiling the recorded waves to the respective wave receiving depths by the hydrophone.

Thus, FAT-Depth Plot has two straight lines with two different slopes. The depth corresponding to the intersecting point of these two lines is considered the lowest depth of the foundation element.

Summary of the PSI Test Outcome

Item	Unit	Value
The point where the slopes of the straight lines in the FAT-Depth Plot changes	M	
Extended Length of tube above EGL	M	
Estimated Pile Length	M	
Wave Velocity in pile	m/sec	
Wave Velocity in soil	m/sec	

4.12.4 Measurement and Payment

Parallel Seismic Test shall be measured in number of tests completed and accepted by the Engineer.

Payment for Parallel Seismic Test shall be full compensation for Pile Instrumentation, labor, transportation, professionals, recording, and reporting including all incidentals necessary to complete the test.

Pay Item No.	Description	Unit Measurement
04/12/01	Parallel Seismic Test (PST)	Nos.

4.13 HIGH STRAIN DYNAMIC TESTING OF PILES

4.13.1 Description

This test method obtains the force and velocity induced in a pile during an axial impact event. Force and velocity are typically derived from measured strain and acceleration. The Engineer may analyze the acquired data using engineering principles and judgment to evaluate the integrity of the pile, the performance of the impact system, and the maximum compressive and tensile stresses occurring in a pile. This Work shall consist in performing a High Strain Dynamic Load Test on Pile in conformance with ASTM D4945 or equivalent standard as approved by the Engineer. Any alternate test methods proposed by the contractor shall be within stipulated cost and at the discretion of Engineer and will have to be prior approved before commencement of work.

4.13.2 Material

The standards for all materials (concrete, rebar, etc.) used in the construction of the load test shall conform to the relevant drawings, project specifications, and RHD Technical Specifications, 2022, or other applicable standards and methods acceptable to the Engineer.

4.13.3 Construction

i) Pile Driving Modeling

The engineer who performs the driving modeling and signal matching shall have a minimum of 5 years of dynamic pile testing and analysis experience. Hammer specifications that will be used for testing shall be prior approved by the Engineer. The contractor shall perform preconstruction wave equation analyses and prepare a summary report of the results. The acceptability of the wave equation report and the adequacy of analyses will be determined by the Engineer.

ii) Testing Operations

Dynamic pile testing field measurements shall be carried out using approved equipment, software and recording equipment. The data collected at the end of initial driving and the beginning of re-strike shall be analyzed using approved signal matching techniques and software.

The equipment required to be attached to the pile shall be appropriately positioned and fixed to the approval of the Engineer.

The hammer and all site equipment used shall be capable of delivering an impact force sufficient to mobilize the specified nominal axial resistance indicated in the design without damaging the pile.

The testing equipment shall monitor pile stresses during driving to prevent pile damage and ensure pile integrity and capacity. If the testing equipment indicates overstressing or damage to the pile, immediately discontinue driving.

iii) Dynamic Measurement and Analysis

Monitoring of pile driving shall begin when pile driving begins unless otherwise approved by the Engineer. The data shall be recorded and processed immediately in the field by the pile driving monitoring equipment and software. Unless monitoring indicates that additional driving will damage the pile, pile driving, and monitoring shall continue until both the specified pile tip elevation and the required nominal axial resistance are reached. For each pile tested, pile driving analysis using signal matching techniques shall be performed for a selected blow at the end of driving to determine the relative resistance from end bearing and skin friction along the pile.

On completion of all field work, the specialist engineer shall prepare a final report covering all aspect of pile load-settlement behaviour including ultimate tip resistance and ultimate shaft

resistance. This final report shall incorporate results of the PDA monitoring, and results of all CAPWAP computer analyses. The results of CAPWAP analysts shall be compared to the PDA results and correlations shall be drawn between the CAPWAP results and the PDA field monitoring results.

4.13.4 Measurement and Payment

High Strain Dynamic Test shall be measured in number of tests completed and accepted by the Engineer. Payment for High Strain Dynamic Test shall be full compensation for Pile Instrumentation, Accelerometer, Strain transducer, Pile Driver Analyser, Impact Pile Driving Hammer, labor, transportation, professionals, recording, and reporting including all incidentals necessary to complete the test.

Pay Item No.	Description	Unit Measurement
04/13/01	High Strain Dynamic Test (HSDT)	Nos.

4.14 ULTRASONIC CROSS-HOLE TESTING

4.14.1 Description

This test method covers procedures for checking the homogeneity and integrity of concrete in deep foundation such as bored piles, drilled shafts, concrete piles, or auger-cast piles. This method can also be extended to diaphragm walls, barrettes, dams, etc. The test measures the propagation time and relative energy of an ultrasonic pulse between parallel access ducts (cross-hole) or in a single tube (single hole) installed in the deep foundation element. This method is most applicable when performed in tubes that are installed. Any alternate test methods proposed by the contractor shall be within stipulated cost and at the discretion of Engineer and will have to be prior approved before commencement of work.

4.14.2 Material

The material and equipment used for testing shall be prior approved by the Engineer. The table below indicates the materials required to be incorporated into the work and approved by the Engineer.

Description	Remarks
Sonic tube and fittings	Pipe, Coupler, End closure
Joint clamp	For joining Tubes
Steel U clips	For joining Tubes to the cage

The table below indicates the equipment required to be incorporated into the work and approved by the Engineer:

Description	Remarks
Depth Wheel / Counter Cable	
Microprocessor based system	For recording and displaying data, converting data from analogue to digital format, analyzing receiver responses, and printing logs.
DC battery power source	

The following documents shall be submitted after product delivery.

- Catalogue and calibration certificate of all equipment's
- Dimensional inspection list (for tubes)

4.14.3 Construction

The Contractor shall submit all relevant details of the method of conduction of cross-hole sonic load tests and equipment he plans to utilize for approval of the Engineer.

i) General

- a. In this test, the transit time of an ultrasonic compressional wave (or p-wave) signal from a signal source in one access tube to a receiver in another access tube is measured from the bottom to the top of a foundation.
- b. Then, knowing tube separation distance, the p-wave velocity is calculated for each depth horizon which results in a profile plot of velocity with respect to depth.
- c. In a nominal foundation with uniform, "good" quality concrete, the acoustic travel time between equidistant tubes will be relatively constant over the depth of the foundation which varies within 3,600 m/sec ~ 4,400 m/sec. Poor quality concrete containing defects (for example, soil inclusion, gravel, water, drilling mud, bentonite, voids, contaminated concrete, or excessive segregation of the constituent particles) has a comparatively lower P-wave speed. By measuring the transit time of an ultrasonic P-wave signal between an ultrasonic transmitter and receiver in two parallel water-filled access ducts cast into the concrete during construction and spaced at a known distance apart, such anomalies may be detected.
- d. On the other hand, an improper concrete mix, voids, or other non-cemented intrusive materials can cause decreased-velocity anomalies. Complete loss of signal may indicate a severe defect.

ii) Testing Arrangement

- a) Sonic tubes are supplied and installed around the perimeter of the reinforcement cage that is installed in the drilled shaft(s) to be tested.
- b) These tubes provide the source and receiver probes with access to the full foundation length from top to bottom.

- c) After placing concrete during pile construction and waiting a minimum of 72 hours for concrete curing, CSL tests can be performed.
- d) Sonic tubes placed on the reinforcement cage should have a minimum concrete cover of diameter approximately 50mm.
- e) Round tubes with a regular internal diameter free of defects and obstructions, including any tube joints, shall be used to permit the free, unobstructed passage of the probes.
- f) Tubes shall be watertight and free from corrosion with clean external faces to ensure a good bond between the concrete and the tubes.
- g) Tubes may be extended with mechanical couplings. Duct tape or other wrapping material to seal the joints and butt-welding of joints should not be used.
- h) When couplings are used, it is required to record their location.
- i) The piling contractor should install tubes such that the CSL probes pass through the entire length of the tube without binding.
- j) It is also required to ensure that the access tubes are plumb and verify that unobstructed passage of the probes is achievable before the CSL.
- k) The tubes should be fit with a watertight shoe on the bottom and a removable cap on the top. Tubes shall be secured to the interior of the reinforcement cage at regular intervals.
- l) Tubes shall be installed uniformly and equidistantly around the circumference such that each tube is spaced parallel for the full length and at the maximum distance possible from each end tube.
- m) Tubes shall not be damaged during installation of the reinforcement cage.
- n) Tube tops shall be capped to prevent debris from entering the access tubes. No excessive torque, hammering or other stresses is applied, which could break the bond between the tube and concrete when removing caps from the tubes.
- o) Number and spacing of vertical sonic pipes dependent on the size of the bored pile shall be specified by the contractor.

iii) Test Procedure

- a) Standard CSL test is to be carried out keeping source and receiver probe in the same horizontal plane.
- b) Both the transducer and receiver are to be lowered to the bottom of two separate tubes before the test is started.
- c) The tubes are attached to the rebar structure in the drilled shaft prior to pouring concrete.
- d) During piling period the tubes are filled with water and capped so that concrete doesn't get inside the tube which is cut off after completion of piling and the water is driven out using water jet cleaning the tube before starting the test.
- e) The tubes are then again filled with water which acts as a coupling agent between a transducer and the drilled shaft.
- f) The transducer generates an ultrasonic signal that propagates through the concrete.
- g) The cables attached to the probes are simultaneously hand-pulled over the depth wheel to steadily bring the probes to the surface.
- h) Prior to pulling, any slack in the cables is removed to ensure accurate depth measurements

in the CSL records.

- i) While traversing a tube pair, CSL acoustic travel time and signal energy measurements made at certain intervals should be specified by the contractor.
- j) These measurements are plotted as depth vs. relative energy and depth vs. first arrival time (FAT). After completion of the test, the pipe is exerted and the hole is filled using non-shrinkable grout having the same concrete strength as the pile or more.
- k) Grout pressure to be applied is considered to be between 0.3MPa to 1.0MPa depending on the viscosity and density.
- l) While in the field, testing agency personnel evaluate the measured data as well as the derived sonic velocities in terms of completeness and accuracy.
- m) A preliminary evaluation of the integrity of the concrete in the foundations tested can generally be provided in the field.

iv) Tolerance

Results of the CSL shall be presented in a written report shall be submitted within (5) working days of completion of testing. The report shall include presentation of CSL logs for all tested tube pairs including:

1. Presentation of the traditional nested signal peak (e.g., “waterfall”) diagram as a function of time plotted versus depth.
2. Computed pulse first arrival time (FAT) or pulse wave speed versus depth.
3. Computed relative pulse energy or amplitude versus depth.

A CSL log shall be presented for each tube pair. The rating of the shaft integrity considers the increases in “first arrival time” (FAT) and the energy reduction relative to the arrival time or energy in a nearby zone of good concrete.

The criteria for evaluation of the concrete from the CSL test shall follow:

Description	Remarks
FAT increase 0 to 10% <u>and</u> Energy Reduction < 6 db	Good (G)
FAT increase 11 to 20% <u>and</u> Energy Reduction of < 9 db	Questionable (Q)
FAT increase 21 to 30% <u>or</u> Energy Reduction of 9 to 12 db	Flaw (F)
FAT increase >31% <u>or</u> Energy Reduction > 12 db	Defect (D)

Flaw or Defect zones, if any, shall be indicated on the logs, listed in a table, and their horizontal and vertical extent and location discussed in the report text. Flaws must be addressed if they affect more than 50% of the profiles. Defects must be addressed if they affect more than one profile (a profile is the result of complete investigation from bottom to top between two tubes) at the same cross section. Flaws or Defects covering the entire cross section define a full layer concern requiring repair. “Addressing” a Flaw or Defect means as a minimum, an evaluation by tomography if the concern is localized (e.g. not across the full section), and/or, depending on the depth to the concern, additional measures like core drilling, repair or replacement, repeat

tests after a long waiting time or testing by other methods (gamma-gamma, low strain, high strain).

4.14.4 Measurement and Payment

Payment shall be made for all costs incurred related to testing including, but not limited to procurement, preparation and installation, conduction of the tests, and subsequent reporting of the results.

Pay Item No.	Description	Unit Measurement
04/15/01	Conduction of Cross-hole sonic load test on xxx diameter pile including reporting of the results	Nos

SECTION-7 GENERAL SPECIFICATIONS

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5.1 CONCRETE FOR STRUCTURES

5.1.1 Description

This work shall consist of the construction of all or portions of structures of cement concrete, of the required grades and types, with or without reinforcement, prestressed reinforcement and with or without admixture, in accordance with these Specifications and to the lines, levels, grades and dimensions shown on the Drawings and required by the Engineer.

Cement concrete shall consist of a mixture of cement, water and coarse and fine aggregate with or without admixture.

5.1.2 Materials

5.1.2.1 Specifications for Materials

A) Cement

Cement shall conform to the requirements of AASHTO Standard Specification M 85 type 1, normal Portland cement, unless other types are indicated on the Drawings or specified by the Engineer.

Cement shall be sampled and tested in accordance with STP Sections 2.6 and 8.

Bagged or bulk cement which has partially set or which contains lumps of caked cement shall be rejected. The use of cement reclaimed from discarded or used bags shall not be permitted.

B) Water

The water used in mixing and curing concrete shall be tested by methods described in AASHTO Test Method T 26. All water shall be clean and free from salt, oil, acid, vegetables or other harmful substances. The use of river water will be subject to the approval of the Engineer.

C) Admixtures

Admixtures or any other additions shall not be used except with the written approval of the Engineer.

Admixtures, if specified or permitted, shall fully conform to the requirements of AASHTO Standard Specification M 194-74.

D) Coarse Aggregate

Coarse aggregate for all types of concrete with the exception of blinding concrete shall consist of hard durable crushed or broken rock and generally conform to the requirements of AASHTO Standard Specification M 80. Coarse aggregate shall be clean, free from dust and other deleterious materials and shall be in Saturated Surface Dry (SSD) condition.

The amounts of deleterious substances shall not exceed the following limits:

- 1) Soft fragments; 2% by mass
- 2) Clay lumps; 0.25% by mass
- 3) Material Passing the 0.075 mm sieve; 0.50% by mass if clay, 1.50% by mass if fracture dust

In addition, coarse aggregates shall comply with the following:

- 1) Thin or elongated pieces; Flakiness Index (STP 7.3.1) less than 30
- 2) The aggregate crushing value (STP 7.7.1) shall be less than 30% and the ten percent fines value (STP 7.7.2) shall be greater than 150 kN.

The grading of coarse aggregate of Nominal maximum size 20 mm shall conform to Table 5.1-1 below. The grading of 40 mm maximum size coarse aggregate shall be in accordance with AASHTO Standard Specification M 80.

Table 5.1-1

Grading Requirements for 20 mm Nominal Maximum Size Coarse Aggregate	
Sieve Size (mm)	% Passing by Weight
25	100
20.0	90 - 100
12.5	20 - 55
10.0	5 - 20
5.0	0 - 5
2.4	-
1.2	-

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In heavily reinforced structures with difficult casting conditions, smaller size aggregates may be used if approved by the Engineer.

E) Fine Aggregate

Fine aggregate shall consist of natural sand and fine aggregates from different sources of supply shall not be mixed or stored in the same pile.

The amounts of deleterious substance when tested in accordance with STP 3.4 shall not exceed the following limits:

- 1) Friable Particles; 0.5% by mass
- 2) Coal and Lignite; 0.5% by mass
- 3) Material passing the 0.075 mm sieve; 3.0% by mass; corresponding FM shall be checked by the Engineer before use
- 4) Any other deleterious materials shall not cause a strength reduction of the concrete of more than 5% in relation to the strength of concrete free of the concerned deleterious material.

The grading shall normally be in accordance with Table 5.1-2. In the event that it is not possible to obtain regular supplies of sand conforming to this grading, the Engineer may approve the adoption of a grading conforming to the requirements of table 4 with additional limits of either C or M of BS 882: 1992. However, any additional costs resulting from changes in aggregate proportions or additional cement contents required to achieve the specified strengths, when using these alternative gradings, shall be borne by the Contractor and shall not be reimbursed.

Table 5.1-2

Grading Requirements for Fine Aggregate	
Sieve Size (mm)	% Passing by Weight
10.0	100
5.0	95 – 100
1.2	45 – 80
0.30	10 – 30
0.15	2 – 10

5.1.2.2 Testing of Materials

A) Cement

Cement shall be in accordance with AASHTO M 85. The Contractor must provide the Engineer with manufacturer's certificates indicating compliance.

Cement shall be sampled and tested for fineness, setting time and strength in accordance with STP 8.1, STP 8.2 and STP 8.3, respectively, at the Contractor's expense. The Contractor shall notify the Engineer of delivery dates so that there will be sufficient time for sampling the cement, either at the mill or upon delivery. If this is not done, the Contractor may be required to re-handle the cement in the store for the purpose of obtaining the required samples.

Sampling shall normally be instructed by the Engineer for every batch of cement prior to this cement being incorporated in the Works.

B) Water

The water proposed by the Contractor to be used in mixing or curing concrete shall be tested by methods described in AASHTO Test Method T 26.

In sampling water for testing, care shall be taken that the containers are clean and that samples are representative.

When comparative tests are made with a water of known satisfactory quality, any indication of unsoundness, marked change in time of setting, or a reduction of more than 10 percent in mortar strength, shall be sufficient cause for rejection of the water under test.

The water shall be tested at a recognized laboratory approved by the Engineer. The test result shall be signed by the laboratory. The water shall be tested before commencement of work or if the source is changed or at any time required by the Engineer. All testing shall be carried out at the Contractor's expense.

C) Admixtures

The Contractor shall submit specifications and samples of any admixtures or additives that he proposes to use to the Engineer at least 28 days before the commencement of construction or manufacture of the particular structure on which he intends to use such admixtures.

Any tests the Engineer may require on concrete mixes on account of the Contractor's proposal to use additives shall be carried out at the expense of the Contractor.

D) Aggregates

1) Selection and Approval

From the aggregate materials proposed by the Contractor, samples shall be selected according to STP Section 2.4 and in the presence of the Engineer. The samples shall

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be tested at the site laboratory or at an approved testing laboratory for conformance with Section 5.1.2.1 of these Specifications.

2) Quality Control

The quality control of the aggregate shall be as directed by Engineer. Gradings shall normally be checked daily.

Moisture contents of fine aggregate shall be determined daily and at any time when a change in moisture content is expected.

If the Contractor proposes to change the source of aggregate, the Engineer shall be informed in advance and in no case less than 3 weeks before the new aggregate shall be used.

5.1.2.3 Composition of Concrete

Classes of Concrete

Concrete for incorporation in the Works shall be of the classes indicated on the Drawings and shall comply with Table 5.1-3.

Table 5.1-3

Concrete	Concrete Characteristic Strength		Nominal Maximum	Minimum
	(N/mm ² @ 28 days)		Size of Coarse Aggregate	Cement Content
	Cylinder	Cube		
Class	(150 x 300 mm)	(150 mm)	(mm)	(Kg/m ³)
10	10	13	40	210
			20	240
15	15	19	40	250
			20	280
20	20	25	40	300

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Concrete	Concrete Characteristic Strength		Nominal Maximum	Minimum
	(N/mm ² @ 28 days)		Size of Coarse Aggregate	Cement Content
	Cylinder	Cube		
			20	320
25	25	31	40	340
			20	360
30	30	37	40	370
			20	400
35	35	44	40	400
			20	430
40	40	50	40	400
			20	430
45	45	56	40	400
			20	430
50	50	62	40	400
			20	430

*Mix design shall conform the target strength as mentioned in the design.

Proportioning

When designing the concrete mix, the Contractor shall consider the following conditions:

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1) Strength

The class of the concrete is to be as shown on the Drawings. The class is the specified characteristic cylinder strength at 28 days. Concrete mixes shall be designed to comply with Specifications Section 5.1.2.4.

2) Water/Cement Ratio

The ratio of free water to cement when using saturated surface dry aggregate shall be maintained at minimum level for hydration and not exceeding 0.50 by weight for all concrete, except for blinding concrete where it shall not exceed 0.6, unless approved by the Engineer.

For concrete in barriers, edge beams and bridge decks directly exposed to traffic or concrete in pile caps or abutments in contact with the ground, the water cement ratio shall not exceed 0.40, unless approved by the Engineer.

3) Minimum Cement Content

As indicated for the respective class in Table 5.1-2 or as specified in the Job Mix Formula.

4) Minimum Filler Content

Filler content (fine aggregate less than 0.25 mm and cement) shall not be less than as follows (except for mass concrete).

Maximum Coarse Aggregate size	(mm)	20	40
Minimum filler content	(kg/m ³ of concrete)	435	350

5) Coarse Aggregate

The maximum size of coarse aggregate will generally be stated on the Drawings; either 40 mm or 20 mm, in accordance with Table 5.1-1. Grading and quality is to comply with the requirements of Section 5.1.2.1(D).

6) Fine Aggregate

The grading and quality is to comply with the requirements of Section 5.1.2.1

7) Workability

The concrete shall be of suitable workability to obtain full compaction. Slumps measured in accordance with STP 9.1 shall not exceed 75 mm unless otherwise indicated on the Drawings or approved by the Engineer.

Trial Mixes

After the Contractor has received approval for the cement and aggregate to be used, he shall prepare trial mixes with concrete of designed proportions to prove and establish workability, strength, water cement/ratio, surface criteria etc. Methods of transporting fresh concrete and the compaction equipment shall be considered. The trial mixes shall be made and compacted in the presence of the Engineer, using the same type of plant and equipment as will be used for the Works.

From each trial mix, cylinders or cubes shall be made and tested in accordance with Section 5.1.2.4.

From the same mix as that from which the test specimens are made, the workability of the concrete shall be determined by the slump test in accordance with STP 9.1. The remainder of the mix shall be cast in a wooden mould and compacted. After 24 hours the sides of the mould shall be struck and the surface examined in order to satisfy the Engineer that an acceptable surface can be obtained with the mix.

The trial mix proportions should be approved if the required strength is obtained from tests carried out in accordance with Section 5.1.2.4 and the consistency and surface is to the satisfaction of the Engineer.

When a mix has been approved, no variations shall be made in the mix proportions, or in the type, size, grading zone or source, of any of the constituents without the consent of the Engineer, who may require further trial mixes to be made before any such variations are approved.

Until the results of trial mixes for a particular class have been approved by the Engineer, no concrete of the relevant class shall be placed in the Works. If the Concrete mix achieves minimum 75% of the target strength as specified in design, in 7 days, the Job Mix Formula may be provisionally approved by the Engineer.

When the Contractor intends to purchase factory-made/ready mix concrete units, trial mixes may be dispensed with evidence provided to satisfy the Engineer that the factory regularly produces concrete which complies with the Specifications. The evidence shall include details of mix proportions, water/cement ratios, slump tests and strengths obtained at 7 and 28 days.

5.1.2.4 Control of Concrete Quality

A) General

The Contractor shall assume the full responsibility for the quality of the concrete conforming to these Specifications and this responsibility shall not be relieved by the testing carried out and approved by the Engineer.

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The Contractor shall thus at his own discretion establish additional testing procedures as necessary.

B) Control of Concrete Production

- a. Materials: Materials used shall be tested in accordance with Section 5.1.2.2.
- b. Plant and Equipment: Batching plants shall be calibrated and tested at standard intervals by any recognized institution arranged by the Contractor subject to approval by the Engineer before any major concrete casting, or at any other time if requested by the Engineer.
- c. Fresh Concrete: The frequency of slump tests shall be as directed by the Engineer, with at least one test per truck/transit of concrete mix.

C) Control of Strength

a. Sampling and Testing

Cube tests may be substituted for cylinder tests if acceptable to both the Engineer and the Contractor. If cube tests are adopted, the concrete characteristic strengths shall be as shown in Table 5.1-2. All other requirements of the Specifications shall equally apply to cubes or cylinders.

The Contractor shall take samples of the concrete for testing. The number, frequency and location shall be decided by the Engineer. A minimum of 3 concrete cubes/cylinders should be taken for each day's casting, or for every 15 m³ of concrete cast in large pours. The slump of concrete samples shall be measured. The procedures for sampling and making cubes/cylinders and testing them shall be as described in STP 9.2.

b. Strength Requirement

The results of the testing shall conform to the strength requirements according to British standard BS5400: Part 7, as given below, or to any mathematically correct statistical test for each casting section.

D) Target Mean Strength

The concrete mix should be designed to have a mean strength greater than the required characteristic strength by at least the current margin.

The current margin for each particular type of concrete mix shall be determined; it may be taken as having the smaller of the values given by (1) or (2) below.

- 1) 1.64 times the standard deviation of tests on at least 100 separate batches of concrete of nominally similar proportions of similar materials and produced over a period not exceeding 12 months by the same plant under similar supervision.

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- 2) 1.64 times the standard deviation of tests on at least 40 separate batches of concrete of nominally similar proportions of similar materials and produced over a period exceeding 5 days but not exceeding 6 months by the same plant under similar supervision.

Where there are insufficient data to satisfy (1) or (2) above, the margin for the initial mix design should be taken as two-thirds of the characteristic strength for concrete. This margin should be used as the current margin only until sufficient data are available to satisfy (1) or (2) above. However, when the required characteristic strength approaches the maximum possible strength of concrete made with a particular aggregate, a smaller margin may be permitted by the Engineer for the initial mix design.

E) Testing Plan

Each cube shall be made from a single sample taken from randomly selected batches of concrete.

Compliance with the specified characteristic strength may be assumed if:

- 3) The average strength determined from any group of four consecutive test cubes exceeds the specified characteristic strength by not less than 0.75 times the current margin, and
- 4) Each individual test result is greater than 95% of the specified characteristic strength.

The current margin should be taken to be two-thirds of the specified characteristic strength for concrete, unless as mentioned above a smaller margin has been established to the satisfaction of the Engineer.

If only one cube result fails to meet the second requirement then that result may be considered to represent only the particular batch of concrete from which that cube was taken provided the average strength of the group satisfies the first requirement.

If more than one cube in a group fails to meet the second requirement or if the average strength of any group of four consecutive test cubes fails to meet the first requirement then all the concrete in all the batches represented by all such cubes shall be deemed not to comply with the strength requirements. For the purposes of this sub-Section, the batches of concrete represented by a group of four consecutive test cubes shall include the batches from which samples were taken to make the first and the last cubes in the group of four, together with all the intervening batches.

F) Action to be taken in the Event of Non-Compliance with the Testing Plan

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When the average strength of four consecutive test cubes fails to meet the first requirement in (F), above, the mix proportions of subsequent batches of concrete shall be rejected. The mix designs shall be reviewed and modified to increase the strength.

The action to be taken in respect of the concrete which is represented by the test-cubes which fail to meet either of the requirements (or not by correct statistical proof can be verified to have the required strength) shall be determined by the Engineer.

The Engineer may also instruct the Contractor to prove statistically the strength, by cutting/taking cores and testing them according to a programme approved by the Engineer at Contractor's expense. The age of the concrete and degree of hardening at the time of the new testing shall be considered. The equivalent cylinder/cube strength shall comply the minimum characteristic strength or as decided by the Engineer.

G) Control of Hardening

If the Contractor wants to remove forms and scaffolding earlier than specified herein, extra test specimens shall be cast by the Contractor in accordance with the instruction of the Engineer. These specimens shall be tested the day before removal of the form. On the basis of the test results the Engineer shall take the final decision on the time for the removal of forms.

For prestressed concrete, extra test specimens shall be cast by the Contractor in accordance with the instructions of the Engineer, to determine the time for tensioning the tendons. On the basis of the test results, the Engineer shall decide upon the time for prestressing the concrete.

5.1.3 Construction Methods

5.1.3.1 General

The Contractor shall in due time and as soon as possible present and discuss his construction methods and work programme with the Engineer and shall obtain his approval before commencement of any work.

The Contractor shall maintain an adequate number of trained and experienced supervisors and foremen at the Site to supervise and control the work.

All construction, other than concrete, shall conform to the requirements prescribed in other Sections of the Specifications, for the particular items of work comprising the complete structure.

5.1.3.2 Scaffolding and Formwork

A) Scaffolding

Details, plans and structural calculations for scaffolding shall be submitted by the Contractor to the Engineer for approval, but in no case shall the Engineer's approval relieve the Contractor of his Contract responsibilities. All scaffolding shall be designed and constructed by the Contractor to provide the necessary rigidity and to support dead and live loads without deflection or deformation. The Engineer may require the Contractor to employ screw jacks or hardwood wedges to take up any settlement in scaffolding and formwork, either before or during the placing of concrete.

Tests may be required by the Engineer of materials proposed by the Contractor for scaffolding. Test loadings of the completed scaffolding may also be required for the determination of flexibility and strength. All expenses associated with testing shall be borne by the Contractor.

Scaffolding which cannot be founded on a satisfactory footing shall be supported on piles, which shall be spaced, driven and removed in a manner approved by the Engineer. When the Contractor wishes to support scaffolding on existing structures, he shall submit his proposals in due time to the Engineer, in writing, including loads from the scaffolding. The Engineer will consider the proposals and respond in writing.

Scaffolding shall be set to give the finished structure a camber, if indicated on the Drawings or specified by the Engineer.

Scaffolding shall remain in place for periods which shall be determined by the Engineer.

B) Formwork

Formwork shall include all temporary or permanent moulds for forming the concrete. Formwork shall be of wood, metal or other approved materials and shall be built mortar tight and rigid enough to maintain the concrete in position during placing, compacting, setting and hardening.

Formwork for exposed surfaces ("wrought form") shall be made of dressed lumber of uniform thickness with or without a form liner of an approved type or shall be of metal sufficiently rigid in itself with no surface blemishes that will impair the quality of the concrete surface finish. No rusty or bent metal forms shall be used. Exposed concrete surfaces shall be provided with formed chamfers, as indicated on the Drawings or instructed by the Engineer.

Rough lumber may be used for surfaces that will not be exposed in the finished structure ("rough form").

All lumber shall be sound, free from warps and twists, sap, shakes, large or loose knots, wavy edge or other defects affecting the strength or appearance of the finished structure.

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All forms shall be set and maintained true to the line designated until the concrete is sufficiently hardened. Forms shall remain in place for periods, which shall be determined by the Engineer. When forms appear to be unsatisfactory in any way, either before or during the placing of concrete, the Engineer may order the work stopped until the defects are corrected.

If requested, the Contractor shall submit to the Engineer working drawings of the forms and also, if requested, calculations to verify the rigidity and strength of the forms.

The shape, strength, rigidity, water tightness and surface smoothness of reused formwork shall be maintained at all times. Any warped or bulged lumber must be re-sized before being reused. Formwork that is unsatisfactory in any respect shall not be reused.

Metal ties or anchorages within the form shall be so constructed as to permit their removal to a depth of at least 50 mm from the face without injury to the concrete. All fittings for metal ties shall be of such design that, upon their removal, the cavities which are left will be of the smallest possible size. The cavities shall be filled with cement mortar and the surface left sound, smooth, even and uniform in colour.

Formwork shall be so constructed that easy cleaning out of any extraneous material inside the formwork can be achieved without disturbing formwork already checked and approved by the Engineer.

Formwork shall be treated with approved non-Steining oil or saturated with water, to facilitate formwork removal. The Engineer may require trials to be carried out before approval is given for the use of a particular type of oil, to ascertain that the oil proposed by the Contractor does not discolour or injure the finished concrete face in any way.

Before placing any concrete, all shavings, loose binding wires, soil, rubbish and all foreign matter shall be removed from the formwork and the formwork shall be carefully and thoroughly washed with water. If not indicated otherwise, the following tolerances of the finished concrete structures shall apply:

Foundations: horizontally ± 30 mm; vertically ± 20 mm

Piers: Horizontally ± 20 mm, vertically ± 10 mm, inclination 1:400

Dimensions of other structural members: + 10 mm, -5 mm

Edge beams and parapets shall be made to such accuracy that no deviations from the correct alignment are visible.

The cross sectional areas of the superstructure of bridges shall in no place deviate more than 3% from the theoretically correct cross sectional areas.

Anchors for bearings, expansion joints, railings, etc. shall be placed within the tolerances indicated on the Drawings or specified by the Engineer.

C) Blinding Concrete

A leveling layer of blinding concrete shall be provided as the permanent bottom form for all concrete structures that will directly bear on prepared soil, whether this blinding concrete is shown on the Drawings or not. The leveling layer of blinding concrete shall be of thickness not less than 75 mm.

D) Approval of Scaffolding and Formwork

If plans and calculations of scaffolding and formwork are requested by the Engineer, no construction of such scaffolding and formwork shall take place before approval by the Engineer, in writing. Such approval shall not relieve the Contractor of his responsibilities under the Contract for the adequacy of scaffolding and formwork.

The Engineer shall have reasonable time for his examination of the Contractor's plans and calculations, especially if scaffolding is introducing temporary loading on new structures. The Contractor shall not be allowed extensions of Contract time due to awaiting such approval.

The Engineer shall inspect all formwork and scaffolding and no concrete shall be placed until the Engineer's approval has been given. Such approval shall not relieve the Contractor of any of his responsibilities under the Contract for the successful completion of the structure.

5.1.3.3 Care and Storage of Concrete Materials

A) Storage of Cement

All cement shall be stored in suitable weatherproof buildings or silos which will protect the cement from dampness. These buildings or silos shall be placed in locations approved by the Engineer. Provisions for storage shall be ample, and the shipments of cement as received shall be separately stored in such manner as to provide easy access for the identification and inspection of each shipment. Storage buildings shall have a capacity for the storage of a sufficient quantity of cement to allow sampling at least 14 days before the cement is to be used. Cement shall meet the test requirements at any time and any cement stored for an elongated time shall be checked and tested before use regardless of whether it has previously been tested.

B) Storage of Aggregates

Aggregates shall be so stored as to prevent the inclusion of foreign material. Aggregates shall not be placed upon the finished roadbed. Aggregates of different sizes and kinds shall be placed in different stockpiles. Stockpiles of blended coarse aggregates shall be built up in successive horizontal layers not more than 1 meter thick. Each layer shall be completed

before the next is started. Should segregation occur, the aggregates shall be recombined to conform to the grading requirements.

Washed aggregates and aggregates produced or manipulated by methods which involve the use of water shall be allowed to drain at least 12 hours before use.

5.1.3.4 Preparations before Casting

Before any major casting, the Contractor shall prepare a complete “casting programme” describing staff and labor, consumption of materials, plant, tools and equipment, reserves of materials, standby plant and equipment, proposed means of handling and placing the concrete, quality controls etc.

No concrete shall be mixed and placed until the Contractor’s casting programme has been approved in writing by the Engineer.

Equipment and tools necessary for handling materials and performing the work, and satisfactory to the Engineer as to design, capacity, and mechanical condition, shall be at the site of the work before casting is started.

If any equipment is not maintained in full working order, or if the equipment as used by the Contractor proves inadequate to obtain the result prescribed, such equipment shall be repaired or other suitable equipment substituted or added at the discretion of the Engineer.

5.1.3.5 Measuring Materials

All material in the mix shall be proportioned by weight or volume, subject to the approval of the Engineer.

When volume batching is proposed by the Contractor, the exact proportions must be converted from trial mix weights to volumes, from bulk densities determined in the laboratory. Written approval from the Engineer is required.

5.1.3.6 Mixing Concrete

A) General

All concrete shall be mixed in batch mixers, either at the site of construction, at a central plant, or in transit. Each mixer shall have attached to it in a prominent place, a manufacturer’s plate showing the capacity of the drum in terms of mixed concrete and the speed of rotation of the mixing drum.

B) Mixers at Local Site of Construction (for minor works)

Mixers at local sites shall be approved drum-type capable of combining the aggregate, cement, and water into a thoroughly mixed and uniform mass within the specified mixing period and of discharging the mixture without segregation. The mixer shall be equipped

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with a suitable charging hopper, water storage and a water measuring device, accurate within 1%. Controls shall be so arranged that the water can be applied only while the mixer is being charged. Suitable equipment for discharging the concrete shall be provided. The mixer shall be cleaned at suitable intervals. The pickup and throw-over blades in the drum shall be replaced when they have lost 10% of their depth.

The mixer shall be operated at a drum speed of between 15 and 20 revolutions per minute. The batched materials shall be so charged into the drum that a portion of the water shall enter in advance of the cement and aggregates and the water shall continue to flow into the drum for a minimum time of 5 seconds after all the cement and aggregates are in the drum. Mixing time shall be measured from the time all materials except water are in the drum and shall, in the case of mixers having a capacity of 1 cubic meter or less, not be less than 50 seconds nor more than 70 seconds. In the case of dual drum mixers, the mixing time shall not include transfer time. The contents of an individual mixer drum shall be removed before a succeeding batch is emptied therein. Any concrete mixed less than the specified minimum time shall be discarded and disposed of by the Contractor at his own expense.

The volume of concrete mixed per batch shall not exceed the mixer's nominal capacity in cubic feet or cubic meters as shown on the manufacturer's guaranteed capacity standard rating plate on the mixer; except that an overload up to 20% of the mixers nominal capacity may be permitted provided concrete test data for strength, segregation and uniform consistency are satisfactory, and provided no spillage of concrete takes place.

Retempering concrete by adding water or by other means shall not be permitted. Concrete which is not of the required consistency at the time of placement shall not be used and shall be discarded and disposed of by the Contractor at his own expense.

C) Central Plant Mixers

These mixers shall be of approved drum type capable of combining the aggregate, cement and water into a thoroughly mixed and uniform mass within the specified mixing period and of discharging the mixture without segregation. Central plant mixers shall be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed. The water system for a central mixer shall be either a calibrated measuring tank or a device and shall not necessarily be an integral part of the mixer.

The mixers shall be cleaned at suitable intervals. This shall be examined daily for changes in interior condition. The pick up and throw-over blades in the drum shall be replaced when they have lost 10% of their depth.

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In addition to the requirements for mixers at local sites detailed above, central plant mixers which have a capacity of between 2 and 5 cubic meters, or greater than 5 cubic meters, should have a minimum mixing time of 90 and 120 seconds respectively, provided tests indicate that the concrete produced is equivalent in strength and uniformity to that attained as stated in the preceding paragraphs.

Mixed concrete shall be transported from the central mixing plant to the site of work in agitator trucks or, upon written permission of the Engineer, in non-agitator trucks. Delivery of concrete shall be so regulated that placing is at a continuous rate unless delayed by the placing operations. The intervals between deliveries of batches shall not be so great as to allow the concrete in place to harden partially, and in no case shall such an interval exceed 30 minutes.

D) Agitator Trucks

Unless otherwise permitted in writing by the Engineer, agitator trucks shall have watertight revolving drums suitably mounted and shall be capable of transporting and discharging the concrete without segregation. The agitating speed of the drum shall not be less than two or more than six revolutions per minute. The volume of mixed concrete permitted in the drum shall not exceed the manufacturer's rating nor exceed 80% the gross volume of the drum.

Upon approval by the Engineer, open-top, revolving-blade truck mixers may be used in lieu of agitating trucks for transportation of central plant mixed concrete.

Gross volume of agitator bodies expressed in cubic feet or cubic meters shall be supplied by the mixer manufacturer. The interval between introduction of water into the mixer drum and final discharge of the concrete from the agitator shall not exceed 45 minutes. During this interval the mix shall be agitated continuously.

E) Non-Agitator Trucks

Bodies of non-agitating equipment shall be smooth, water-tight metal containers equipped with gates that will permit control of the discharge of the concrete. Covers shall be provided when needed for protection against the weather.

The non-agitating equipment shall permit delivery of the concrete to the site of the work in a thoroughly mixed and uniform mass with a satisfactory degree of discharge.

Uniformity shall be satisfactory if samples from the one-quarter and three quarter points of the load do not differ by more than 30 mm in slump. Discharge of concrete shall be completed within 30 minutes after the introduction of the mixing water to the cement and aggregate.

F) Truck or Transit Mixers

These shall be equipped with electrically actuated counters by which the number of revolutions of the drum or blades may readily be verified and the counters shall be actuated

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at the commencement of mixing operations at designated mixing speeds. The mixer when loaded shall not be filled to more than 60% of the drum gross volume. The mixer shall be capable of combining the ingredients of the concrete into a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity.

Except when intended for use exclusively as agitators; truck mixers shall be provided with a water measuring device to measure accurately the quantity of water for each batch. The delivered amount of water shall be within plus or minus 1% of the indicated amount.

Truck mixers may be used for complete mixing at the batch plant and as truck agitators for delivery of concrete to job sites, or they may be used for complete mixing of the concrete at the job site. They shall either be a closed watertight revolving drum or an open top revolving blade or paddle type.

The amount of mixing shall be designated in number of revolutions of the mixer drum. When a truck mixer is used for complete mixing, each batch of concrete shall be mixed for between 70 and 100 revolutions of the drum or blades at the rate of rotation designated by the manufacturer of the equipment as the "mixing speed". Such designation shall appear on a metal plate attached to the mixer. If the batch is at least 0.5 cubic meters less than guaranteed capacity, the number of revolutions at mixing speed may be reduced to not less than 50. Mixing in excess of 100 revolutions shall be at the agitating speed. All materials, including the mixing water, shall be in the mixer drum before actuating the revolution counter which will indicate the number of revolutions of the drum or blades.

When wash water (flush water) is used as a portion of the mixing water for the succeeding batch, it shall be accurately measured and taken into account in determining the amount of additional mixing water required. When wash water is carried on the truck mixer, it shall be carried in a compartment separate from the one used for carrying or measuring the mixing water. The Engineer will specify the amount of wash or flush water, when permitted; any may specify a "dry" drum if wash water is used without measurement or without supervision.

When a truck is used for complete mixing at the batch plant, mixing operations shall begin within 30 minutes after the cement has been added to the aggregate. After mixing, the truck mixer shall be used as an agitator, when transporting concrete, at the speed designated by the manufacturer of the equipment as agitating speed. Concrete discharge shall be completed within 45 minutes after the addition of the cement to the aggregates. Each batch of concrete delivered at the job site shall be accompanied by a time slip issued at the batching plant, bearing the time of departure therefrom. When the truck mixer is used for the complete mixing of the concrete at the job site, the mixing operation shall begin within 30 minutes after the cement has been added to the aggregates.

The rate of discharge of the plastic concrete from the mixer drum shall be controlled by the speed of rotation of the drum in the discharge direction with the discharge gate fully open.

5.1.3.7 Handling and Placing Concrete

The temperature of concrete at the time of placing shall not exceed 35°C. In preparation for the placing of concrete all sawdust, chips and other construction debris and extraneous matter shall be removed from the interior of forms. Struts, stays and braces, serving temporarily to hold the forms in correct shape and alignment, pending the placing of concrete at their locations, shall be removed when the concrete placing has reached an elevation rendering their service unnecessary. These temporary members shall be entirely removed from the forms and not buried in the concrete.

Concrete must reach its final position in the forms within 20 minutes of the completion of mixing, or as directed by the Engineer. Concrete shall be placed so as to avoid segregation of the materials and the displacement of the reinforcement. The use of long troughs, chutes and pipes for conveying concrete from the mixer to the forms shall be permitted only on written authorization of the Engineer. In case an inferior quality of concrete is produced by the use of such conveyors, the Engineer may order discontinuance of their use and the institution of a satisfactory method of placing.

Open troughs and chutes shall be of metal or metal lined. Where long steep slopes are required, the chutes shall be equipped with baffles or be in short lengths that reverse the direction of movement.

All chutes, troughs and pipes shall be kept clean and free from coatings of hardened concrete by thoroughly flushing with water after each run. Water used for flushing shall be discharged clear of the structure.

When placing operations would involve dropping the concrete more than 1.5 m, it shall be deposited through sheet metal or other approved pipes. As far as practicable, the pipes shall be kept full of concrete during placing and their lower ends shall be kept buried in the newly placed concrete. After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the ends of reinforcement bars which project.

Concrete, during and immediately after depositing, shall be thoroughly compacted. The compaction shall be done by mechanical vibration subject of the following provisions:

- 1) The vibration shall be internal unless special authorization of other methods is given by the Engineer or as provided herein.
- 2) Vibrators shall be of a type and design approved by the Engineer. They shall be capable of transmitting vibration to the concrete at frequencies of not less than 4,500 impulses per minute.
- 3) The intensity of vibration shall be such as to visibly affect a mass of concrete of 20 mm slump over a radius of at least 450 mm.
- 4) The Contractor shall provide a sufficient number of vibrators to properly compact each batch immediately after it is placed in the forms.

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- 5) Vibrators shall be manipulated to thoroughly work the concrete around the reinforcement and embedded fixtures, and into the corners and angles of the forms. Vibration shall be applied at the point of deposit and in the area of freshly deposited concrete. The vibrators shall be inserted into the concrete in a fast manner but will be withdrawn from the concrete slowly. The vibration shall be of sufficient duration and intensity to thoroughly compact the concrete but shall not be continued so as to cause segregation. Vibration shall not be continued at any one point to the extent that localized areas of grout are formed. Application of vibrators shall be at points uniformly spaced and not further apart than twice the radius over which the vibration is visibly effective. The influence zone of vibration shall be such that it uniformly covers all fresh concrete.
- 6) Vibration shall not be applied directly or through the reinforcement to sections or layers of concrete which have hardened to the degree that the concrete ceases to be plastic under vibration. It shall not be used to make concrete flow in the forms over distances so great as to cause segregation, and vibrators shall not be used to transport concrete in the forms.
- 7) Vibration shall be supplemented by such spading as is necessary to ensure smooth surfaces and dense concrete along form surfaces and in corners and locations impossible to reach with the vibrators.
- 8) The provisions of this Section shall also apply to precast piling, concrete cribbing and other precast members except that, if approved by the Engineer, the manufacturer's methods of vibration may be used.

Concrete shall be placed in horizontal layers not more than 600 mm thick except as hereinafter provided. When less than a complete layer is placed in one operation, it shall be terminated in a vertical bulkhead. Each layer shall be placed and compacted before the preceding batch has taken initial set to prevent injury to the green concrete and avoid surfaces of separation between the batches. Each layer shall be compacted so as to avoid the formation of a construction joint with a preceding layer which has not taken initial set.

When the placing of concrete is temporarily discontinued, the concrete, after becoming firm enough to retain its form, shall be cleaned of laitance and other objectionable material to a sufficient depth to expose sound concrete. To avoid visible joints as far as possible upon exposed faces, the top surface of the concrete adjacent to the forms shall be smoothed with a trowel. Where a "feather edge" might be produced at a construction joint, as in the sloped top surface of a wing wall, an inset form shall be used to produce a blocked out portion in the preceding layer which shall produce an edge thickness of not less than 150 mm in the succeeding layer. Work shall not be discontinued within 450 mm of the top of any face, unless provision has been made for a coping less than 450 mm thick, in which case, if permitted by the Engineer, a construction joint may be made at the underside of the coping.

Immediately following the discontinuance of placing concrete all accumulations of mortar splashed upon the reinforcement steel and the surfaces of forms shall be removed. Dried

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mortar chips and dust shall not be puddle into the unset concrete. If the accumulations are not removed prior to the concrete becoming set, care shall be exercised not to injure or break the concrete-steel bond at and near the surface of the concrete, while cleaning the reinforcement steel.

For simple spans, concrete shall preferably be deposited by beginning at the center of the span and working from the center toward the ends. Concrete in girders shall be deposited uniformly for the full length of the girder and brought up evenly in horizontal layers. For continuous spans, the concrete placing sequence shall be as shown on the plans or agreed on by the Engineer.

Concrete in slab and girder haunches less than 1.0 meter in height shall be placed at the same time as that in the girder stem.

Concrete in slab spans shall be placed in one continuous operation for each span unless otherwise provided.

Concrete in T-beam or deck girder spans may be placed in one continuous operation if permitted by the Engineer.

Concrete in columns and pier shafts shall be placed in one continuous operation, unless otherwise directed.

Unless otherwise permitted by the Engineer, no concrete shall be placed in the superstructure until the column forms have been stripped sufficiently to determine the character of the concrete in the columns. The load of the superstructure shall not be applied to the supporting structures until they have been in place at least 14 days, unless otherwise permitted by the Engineer.

Pneumatic placing of concrete shall be permitted only if authorized by the Engineer. The equipment shall be so arranged that vibration does not damage freshly placed concrete.

Where concrete is conveyed and placed by pneumatic means the equipment shall be suitable in kind and adequate in capacity for the work. The machine shall be located as close as practicable to the place of deposit. The position of the discharge end of the line shall not be more than 3 meters from the point of deposit. The discharge lines shall be horizontal or inclined upwards from the machine. At the conclusion of placement the entire equipment shall be thoroughly cleaned.

Placement of concrete by pumping shall be permitted only if authorized by the Engineer. The equipment shall be so arranged that vibrations do not damage freshly placed concrete. Where concrete is conveyed and placed by mechanically applied pressure, the equipment shall be suitable in kind and adequate in capacity for the work. The operation of the pump shall be such that a continuous stream of concrete without air pockets is produced. When

pumping is completed, the concrete remaining in the pipeline, if it is to be used, shall be ejected in such a manner that there is not contamination of the concrete or separation of the ingredients. After this operation, the entire equipment shall be thoroughly cleaned.

5.1.3.8 Perforations and Embedment of Special Devices

The Contractor is responsible for determining in advance of making any concrete pours, all requirements for perforation of concrete sections or embedment therein of special devices of other trades, such as conduits, pipes, weep holes, drainage pipes, fastenings, etc. Any concrete poured without prior provision having been made, shall be subject to correction at the Contractor's expense.

Special devices to be embedded:

- Expansion joints
- Drain outlets including fixing bolts for down pipes
- Bolts and inserts for sign posts
- Bolts and inserts for various purposes regarding inspection and maintenance as directed by the Engineer

Other devices not mentioned above shall be shown on the Drawings or directed by the Engineer. The inserts and fittings should conform to Sections 5.9 and 5.10 of this Specification.

5.1.3.9 Finishing Concrete Surfaces

One of the following types of finishing shall be applied to concrete surfaces:

Type A - Concrete Decks

Immediately after placing concrete, concrete decks shall be struck off using templates to provide proper crowns and shall be finished smooth to the correct levels. Finish shall be slightly but uniformly roughened by brushing. The finished surface shall not vary more than 10 mm from a 3 meter straight edge placed in any direction on the roadway.

Type B - Kerb and Sidewalk Surface

Exposed faces of kerbs and sidewalks shall be finished to true lines and grades. The kerb surface shall be wood floated to a smooth but not slippery finish. Sidewalk surfaces shall be slightly but uniformly roughened by brushing.

Type C - Ordinary Finish

An ordinary finish is defined as the finish left on a surface after the removal of the forms when all holes left by form ties have been filled, and any minor surface defects have been repaired. The surface shall be true and even, free from depressions or projections.

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The concrete in bridge seats, caps, and tops of walls shall be struck off with a straight edge and floated to true grade. Under no circumstances shall the use of mortar topping for concrete surfaces be permitted.

Type D - Rubbed Finish

After the removal of forms the rubbing of concrete shall be started as soon as its condition permits. Immediately before starting this work the concrete shall be kept thoroughly saturated with water for a minimum period of three hours. Sufficient time shall have elapsed before the wetting down to allow the mortar used in patching to have thoroughly set. A medium coarse carborundum stone shall be used for rubbing a small amount of mortar on the face. The mortar used shall be composed of cement and fine aggregate mixed in the same proportions as that used in the concrete being finished. Rubbing shall be continued until all form marks, projections, and irregularities have been removed, all voids filled, and a uniform surface has been obtained. The paste produced by this rubbing shall be left in place at this time. The final finish shall be obtained by rubbing with a fine carborundum stone and water until the entire surface is of a smooth texture and uniform colour.

After the final rubbing has been completed and the surface has dried, burlap shall be used to remove loose powder. The final surface shall be free from unsound patches, paste, powder and objectionable marks.

Type E - Bushhammer Finish

Bushhammering shall be carried out by treating the surface with an approved heavy duty power hammer fitted with a multi-point tool which shall be operated over the surface to remove 5 to 6 mm of concrete paste and expose maximum areas of coarse aggregate.

Aggregate left embedded shall not be fractured or loose. 25 mm wide bands at all corners and arrises shall be left as cast. The finish surface shall be even and of uniform appearance and shall be washed with water upon completion.

Type F - Ribbed Finish

Ribs shall be vertical and to the dimensions shown on the Drawings. The direction of the grain of the timber forming the ribs shall be vertical.

Type G – fair-faced finish

Cast-in-place fair-faced concrete works with $f_{cr}=33.5$ MPa and $f_c=25$ MPa at 28 days on standard cylinders by using 75% of OPC and 25% of white cement conforming to BDS EN-197-1-CEM-I, 52.5N, best quality Sylhet sand or coarse sand of equivalent F.M. 2.2, 20 mm down and well graded stone chips conforming to ASTM C-33 (Aggregate grading as per table shown in technical specification) at mix ratio of 1:1.5:3, adding coloring pigment admixture (satisfying ASTM C979) as per architectural design, conforming to the

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standard practice of code ACI / BNBC / ASTM including conducting necessary tests, screening sand and chips through proper sieves, washing, making and placing shutter in position maintaining true to plumb, making shutter water tight properly, placing reinforcement in position, including pouring of concrete in form, compacting by vibrator machine and curing at least for 28 days, removing centering-shuttering after specified time approved; including cost of water, electricity, other charges etc. all complete, approved and accepted by the Engineer-in-charge.

5.1.3.10 Construction Joints

A) General

Construction joints shall be made only where located on the plans or shown in the pouring schedule, unless otherwise approved by the Engineer.

If not detailed on the plans, or in the case of emergency, construction joints shall be placed as directed by the Engineer. Shear keys or inclined reinforcement shall be used where necessary to transmit shear or bond the two sections together.

B) Bonding

Before depositing new concrete on or against concrete which has hardened, the forms shall be re-tightened. The surface of the hardened concrete shall be roughened as required by the Engineer, in a manner that does not leave loosened particles of aggregate or damaged concrete at the surface. It shall be thoroughly cleaned of foreign matter and laitance, and saturated with water. To ensure an excess of mortar at the juncture of the hardened and the newly deposited concrete, the cleaned and saturated surfaces, including vertical and inclined surfaces, shall first be thoroughly covered with a thin coating of mortar or neat cement grout against which the new concrete shall be placed before the grout has attained its initial set. Bonding agent may be used as per instruction of the Engineer.

The placing of concrete shall be carried continuously from joint to joint. The face edges of all joints which are exposed to view shall be carefully finished true to line and elevation.

5.1.3.11 Curing Concrete

All concrete surfaces shall be kept thoroughly wet for at least 7 days after placing. Bridge deck and sidewalk slabs shall be covered with wet thick cloth made with jute or suitable geotextile immediately after final finishing of the surface. and Curing of concrete for slabs with large open surface shall be initiated immediately after pouring of concrete. This material shall remain in place for the full curing period or may be removed and replaced with sand when the concrete has hardened sufficiently to prevent marking. In both cases the materials shall be kept thoroughly wet for the entire curing period. All other surfaces if not protected by forms, shall be kept thoroughly wet, either by sprinkling or mud curing (pond created by wet clay and surface covered by wet soil necessarily immediate after the

initial setting time) or by the use of wet burlap until the end of the curing period. The wood forms are allowed to remain in place during the curing period, but they shall be kept moist at all times to prevent openings at joints.

After a period of 7 days, the concrete shall be watered daily at certain intervals approved by the Engineer to avoid drying out of the surface. This shall take place during the following 2 weeks. The water used shall be the same as used in concrete mixes unless otherwise approved by the Engineer.

Curing agents may be used as per instruction of the Engineer.

Any proposal from the Contractor for the use of liquid membrane curing compound shall be subject to the approval of the Engineer.

5.1.3.12 Removal of Scaffolding and Formwork

Forms and scaffolding shall not be removed without the approval of the Engineer. The Engineer's approval shall not relieve the Contractor of his Contract responsibilities. Any ken ledge blocks and bracing shall be removed at the same time as the forms and in no case shall any portion of the wood forms be left in the concrete.

Forms used on exposed vertical faces shall remain in place for periods which shall be determined by the Engineer and normally not less than 3 days.

Supporting scaffolding and forms under slabs, beams and girders shall normally remain in place until the full required strength of the concrete has been obtained. If a shorter period is requested, this may be permitted by the Engineer. In such case, special test specimens (see Section 5.1.2.4) shall be cast to monitor the hardening. Removal methodology of scaffolding and formworks shall be proposed the contractor and approved by the Engineer.

All structures shall be fully stripped before adjacent structures are cast.

5.1.3.13 Repair of Concrete

As soon as the form has been stripped, the Contractor shall advise the Engineer who shall inspect the concrete before any improvement of the surface takes place.

All wire or metal devices used for securing the formwork which project from or appear on the surface of the finished concrete shall be removed or cut back to at least a depth equal to the required reinforcement cover. All holes and pockets so formed shall be filled with cement mortar mixed in the same proportions as the fine aggregate to cement of the concrete mix used for that particular section of the structure, after the surface to be patched has been thoroughly cleaned and wetted to receive the patch. In case of cracks developed acceptable to the Engineer shall be repaired using epoxy-based grout as approved by the Engineer.

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Excessive honeycombing shall be sufficient to cause rejection of portions of the structure containing this honeycombing. The Contractor, on receipt of written orders from the Engineer, shall remove and rebuild such portions of the structure at his own expense.

Smaller honeycombing and other defects can be repaired if permitted by the Engineer. Structural, maintenance and aesthetical points of view shall be taken into consideration before such approval, if any, may be given. The method of repair shall be approved by the Engineer and an extension of period for a certain part of the performance bond may be required.

5.1.3.14 Depositing Concrete under Water

Concrete shall not be deposited in water except with the approval of the Engineer and under his immediate supervision; and in this case the method of placing shall be as defined in this Section.

Concrete placed under water shall be carefully placed in a compact mass, in its final position, by means of a tremie tube and shall not be disturbed after being deposited. Special care must be exercised to maintain still water at the point of deposit. Concrete shall not be placed in running water. The method of depositing concrete shall be so regulated as to produce approximately horizontal surfaces.

Concrete seals shall be placed in one continuous operation. When a tremie tube or pipe is used, it shall consist of a tube or pipe not less than 150 mm in diameter. All joints in the tube shall be watertight. The means of supporting the tremie tube shall be such as to permit free movement of the discharge end over the entire top of the concrete and to permit its being lowered rapidly when necessary to choke off or retard the flow. The tremie tube shall be filled by a method that prevents washing of the concrete. The discharge end shall be completely submerged in concrete at all times and the tremie tube shall be kept full. Concrete slump shall not be less than 150 mm.

Dewatering shall proceed only when the concrete seal is considered strong enough to withstand any pressure to be exerted upon it. This time shall be decided by the Engineer.

All laitance or other unsatisfactory material shall be removed from the exposed surface by scraping, jetting, chipping or other means, which do not injure the seal unduly.

5.1.3.15 Factory Made Precast Concrete Elements

Any supplier of precast concrete elements (concrete blocks, piles, paving blocks etc.) shall be approved in writing by the Engineer. Such approval can be withdrawn at any time.

Concrete work in precast concrete elements shall fully conform to all relevant Sections of these Specifications.

The supplier shall maintain laboratory facilities of the same standard as the site laboratory.

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Unless otherwise approved by the Engineer, precast concrete members shall not be moved from the casting position until the concrete has attained a compressive strength of 80% of the specified 28 day strength, nor transported until it has developed a strength of 90% of the specified 28 day strength.

Extreme care shall be exercised in handling and moving precast concrete members. Precast girders and slabs shall be transported in an upright position. Shock shall be avoided and the points of support and directions of the reactions with respect to the member shall be approximately the same during transportation and storage as when the member is in its final position. If the Contractor deems it expedient to transport or store precast units in other than this position, this shall be at the Contractor's risk, after notifying the Engineer of his intention to do so. Any rejected unit shall be replaced at the Contractor's expense by an acceptable unit.

Proposed details on the handling and transportation of precast concrete members shall be submitted in writing by the Contractor, to the Engineer, for his approval.

Each precast member is to be uniquely and permanently marked so as to show its type, date of casting and any other information required by the Engineer.

5.1.3.16 Control of Heat in Structures

In structures of major dimensions i.e., pile caps, etc. the heat deriving from the hardening of the concrete shall be controlled by the Contractor. Temperature gradients introducing risk of cracking shall not occur and the temperature shall not exceed 70°C.

To control heat of hydration cold water circulation method shall be used as per instruction of the Engineer.

The Contractor shall submit timely proposals with details methodology for avoiding excessive heat generation, such as the cooling of aggregates before mixing, to the Engineer for approval.

5.1.3.17 Grouting of Ducts for Prestressing Tendons

A) General

The purpose of grouting is to provide permanent protection to the post-tensioning steel and to achieve bond between the prestressing steel and the concrete.

The time of commencement of grouting shall be approved by the Engineer. The Contractor shall give timely notice of grouting to the Engineer.

Definition of Terms

A) Admixture. Any material added to the grout other than Portland cement and water.

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Duct. The hole or void provided in the concrete for the tendon used in post-tensioning, formed by sheathing.

Grout. A mixture of cement and water with or without admixtures.

Grout opening or vent. An inlet, outlet or vent in the duct for grout, water or air.

Grout Openings or Vents

All ducts shall have grout openings at both ends. For draped cables, all high points should have a grout vent except where cable curvature is small, such as in continuous slabs. All grout openings or vents shall include provisions for preventing grout leakage.

B) Equipment

- 1) The grouting equipment shall include a mixer capable of continuous mechanical mixing which will produce a grout free of lumps and undispersed cement. The equipment shall be able to pump the mixed grout in a manner which will comply with all provisions of the recommended practice.
- 2) Accessory equipment which will achieve accurate solid and liquid measures shall be provided to batch all materials.
- 3) The pump shall be a positive displacement type and be able to produce an outlet pressure of at least 10.5 kg/cm². The pump should have seals adequate to prevent introduction of oil, air or other foreign substances into the grout and to prevent loss of grout or water.
- 4) A pressure gauge having a full scale reading of no greater than 21 kg/cm² shall be placed at some point in the grout line between the pump outlet and the duct inlet.
- 5) The grouting equipment shall contain a screen having clear openings of 3.2 mm maximum size to screen the grout prior to its introduction into the grout pump. If a pump with a thixotropic additive is used, a screen opening of 4.8 mm is satisfactory. This screen shall be easily accessible for inspection and cleaning
- 6) The grouting equipment shall utilize gravity feed to the pump inlet from a hopper attached to and directly over it. The hopper must be kept at least partially full of grout at all times during the pumping operation to prevent air from being drawn into the post-tensioning duct.
- 7) Under normal conditions, the grouting equipment shall be capable of continuously grouting the largest tendon on the Works in no more than 20 minutes.

C) Materials

- 1) Portland Cement: Portland cement shall conform to one of the following: Specifications for Portland cement - AASHTO M 85, type 1, 2 or 3.
Cement used for grouting shall be fresh and shall not contain any lumps or other indication of hydration or “pack set”.
- 2) Water: The water used in the grout shall be potable, clean and free of injurious

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quantities known to be harmful to Portland cement or prestressing steel.

- 3) Admixtures: Admixtures, if used, shall impart the properties of low water content, good flowability, minimum bleed and moderate expansion. Their formulation shall contain no chemicals in quantities that may have harmful effects on the prestressing steel or cement. Admixtures containing chlorides, fluorides, sulphites and nitrates shall not be used.

Aluminium powder of the proper fineness and quantity or other approved gas evolving material which is well dispersed through the other admixture may be used to obtain 5 to 10 percent unrestrained expansion of the grout.

All admixtures shall be approved by the Engineer and used in accordance with the instructions of the manufacturer.

D) Mixing of Grout

- 1) Water shall be added to the mixer first, followed by Portland cement and admixture, or as required by the admixture manufacturer.
- 2) Mixing shall be of such duration as to obtain a uniform thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixture. The grout shall be continuously agitated until it is pumped.
- 3) Water shall not be added to increase grout flowability which has been decreased by delayed use of the grout.
- 4) Proportions of materials shall be based on tests made on the grout before grouting is begun, or may be selected based on prior documented experience with similar materials and equipment and under comparable field conditions (weather, temperature, etc.). The water content shall be the minimum necessary for proper placement and when type 1 or 2 cement is used shall not exceed a water/cement ratio of 0.45.

The water content required for type 3 cement shall be established for a particular brand based on tests. The pumpability of the grout may be determined by the Engineer in accordance with the U.S. Corps of Engineers Method CRD-C79. When this method is used, the efflux time of the grout sample immediately after mixing shall not be less than 11 seconds. The flow cone test does not apply to grout which incorporates a thixotropic additive.

Trial mixes shall be carried out on site with the selected constituents to demonstrate the physical properties of the grout.

E) Grouting

Preparation of duct:

- Flushing of metal ducts shall be carried out, if considered necessary by the Engineer.
- The pumping pressure at the tendon inlet shall not exceed the value which may develop cracking in surrounding concrete.

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- If the actual grouting pressure exceeds the maximum recommended pump pressure, grout may be injected at any vent which has been or is ready to be capped, as long as one-way flow of grout is maintained. If this procedure is used, then the vent, which is to be used for injection, shall be fitted with a positive shutoff.
- When one-way flow of grout cannot be maintained as outlined above, the grout shall be immediately flushed out of the duct with water.

Grout shall be pumped through the duct and continuously wasted at the outlet pipe until no visible slugs of water or air are ejected. To ensure that the tendon remains filled with grout, the outlet and/or inlet shall then be closed. Plugs, caps or valves thus required shall not be removed or opened until the grout has set.

F) Temperature

Grout shall not be above 35°C during mixing or pumping. If necessary the mixing water shall be cooled.

5.1.3.18 Loading

No superstructure load shall be placed upon finished bents, piers, or abutments until the Engineer so directs but in no case shall any load of any kind be placed until the concrete has completed curing.

The Contractor shall not place any temporary loads on deck slabs unless allowed by the Engineer in writing (see Section 5.1.3.2). Bridge deck slabs shall be opened to traffic only when so directed by the Engineer and generally not sooner than 28 days after the placing of the concrete has been completed.

5.1.3.19 Backfill to Structures

All spaces which have been excavated and the volumes of which are not occupied by the concrete structure shall be backfilled and compacted with acceptable material in accordance with the provisions of Section 2.5 as directed by the Engineer.

5.1.3.20 Cleaning Up

Upon completion of a structure and before final acceptance, the Contractor shall remove all forms and scaffolding etc. down to 0.5 meters below the finished ground line. Excavated, or useless materials, rubbish etc. shall be removed from the Site and the Site shall be left in a neat and tidy condition satisfactory to the Engineer.

5.1.4 Specifications for higher strength Concretes (40, 45, 50 & 60 MPa)

Providing and laying Cement Concrete works with minimum cement content as per standard practice of Code AASHTO/ ASTM and cement conforming to BDS EN 197-1 : 2003 CEM-I 52.5N / ASTM C150 Type-1, silica fume conforming to ASTM C 1240, high

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range water reducing admixture of complying type F/ G under ASTM C 494 (Doses of admixture to be fixed by the mix design) for smart dynamic concrete (i.e. Low fines self-compacting concrete), sand of minimum FM 2.80 and 20mm down well graded crushed stone chips broken from boulders (LAA value not exceeding 25) conforming to ASTM C 33 , including breaking stone boulders into chips, screening through proper sieves, making and placing shutter in position, making shutter water-tight properly, placing non prestressing reinforcement, HT Strand, sheath, anchorage in position, mixing in mechanized batch mix plant & pumping using line pump or boom placer, maintaining allowable slump of 75mm to 100mm, casting in forms, compacting by mechanical vibrator machine, curing at least for 28 days, removing shutter after specified time period, finishing, launching, shifting & placing in position etc. including cost of water, electricity, other incidental charges etc. all complete as per design, drawing, specification & direction of E-I-C. The Mix Design shall have to be approved by the Engineer.

For High Performance Concrete and Ultra-High Performance Concrete will be prepared in accordance with ASTM 1856/C1856M-17 and the design shall be approved by BRRL, RHD or the Engineer.

5.1.5 Measurement

Concrete shall be measured by the number of cubic meters of class and maximum coarse aggregate size indicated on the Drawings complete in place and accepted by the Engineer. In computing quantities, the dimensions used shall be those shown on the Drawings. No deduction from the measured quantity shall be made for drainage, , conduits, chamfers, reinforcement bars, prestressing tendons, water stops or pile heads embedded in concrete.

Reinforcing and prestressing steel shall be measured for payment as described in Specifications Sections 5.2 and 5.3.

Formwork, scaffolding, construction joints and surface finishes shall **Not** be measured separately but shall be an integral part of the concrete items unless otherwise specified.

Blinding concrete for concrete structures bearing directly on prepared soil shall be measured in cubic meter. . The measured area will be the same as that of the base area of the concrete structure.

5.1.6 Payment

Concrete of the classes and maximum coarse aggregate sizes shown on the Drawings and measured as provided in Section 5.1.4 shall be paid for at the Contract unit prices per cubic meter. The Contractor's rates shall include all trial mixes (as specified in Section 5.1.2.3), mixing, transporting, placing and compacting the concrete. The rates shall also include all

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concrete finishing, the supply, placing and building in of weep pipes or pipe sleeves, forming construction joints, forming holes or pockets not exceeding 0.15 m³ each.

The Contractor's rates shall be fully inclusive of the cost of all labor and materials in providing and erecting all formwork, falsework and centering and for their subsequent removal.

Payment for precast units shall include all concrete, prestressing tendons, formwork, finishing, transport and erection and where applicable any bolts, bedding or other devices necessary to fix them in their permanent position.

Payment for single layer brick flat soling shall include the supply of all required materials and all labor, equipment, tools and incidentals necessary to complete the work.

Pay items shall be (the rates shall be inclusive of scaffolding and formworks):

05/01/02(a)	Concrete Class as Detailed on Drawings (Class 10)	cu meter
05/01/02(b)	Concrete class as Detailed on Drawings (Class 20)	cu meter
05/01/02(c)	Concrete class-25 (Foundation i.e. Pile, Well, etc.)	cu meter
05/01/02(d)	Concrete class -25 (Vertical member i.e. Pier Column, Abutment Wall, Wing Wall etc.)	cu meter
05/01/02(e)	Concrete class -25 (Culvert, Retaining Wall, Toe wall etc.)	cu meter
05/01/02(f)	Concrete class-25 (Abutment Pile cap, Pier Pile cap, Pier Cap, Girder, cross girder, diaphragm, beam etc.)	cu meter
05/01/02(g)	Concrete class-25 (Side walk, wheel guard, curb, Rail & Post etc.	cu meter
05/01/02(h)	Concrete class - 25 (RCC Pavement work)	cu meter
05/01/02(i)	Concrete class-35 (Deck slab, side walk, wheel guard, curb etc.)	cu meter

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05/01/02(j)	Concrete Class - 35 as Detailed on Drawings	cu meter
05/01/02(k)	Concrete Class – 40 (Pre-stressed Girder)	cu meter
05/01/02(l)	Concrete Class – 45 (Pre-stressed Girder)	cu meter
05/01/02(m)	Concrete Class – 50 (Pre-stressed Girder)	cu meter
05/01/02(n)	Concrete Class – 60 (Pre-stressed Girder)	cu meter

5.2 REINFORCEMENT

5.2.1 Description

This work shall consist of furnishing and placing bars of the grade, type, and size shown in accordance with these Specifications and in conformity with the requirements shown on the Drawings.

5.2.2 Materials

5.2.2.1 Bar Reinforcement

All mild steel bars shall have a yield stress not less than 240 N/mm² and shall conform to ASTM A615 or ASTM A706 or BDS ISO 6935-2:2016 or the latest such equivalent standard or specification in force that is considered by the Engineer to apply.

All high yield steel bars shall be deformed bars with a yield stress not less than 400 N/mm² and shall conform to ASTM A615 or ASTM A706 or BDS ISO 6935-2:2016 or the latest such equivalent standard or specification in force that is considered by the Engineer to apply.

The production process of the reinforced bar is at the discretion of the manufacturer, as described in BDS ISO 6935-2: 2016. However, various types of deformed bars will be permitted, as mentioned in following table:

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Ribbed or deformed bar reinforcement
Grade 300 (B 300DWR): Ribbed or Deformed bar produced and marked as per BDS ISO 6935-2:2016 with minimum yield strength, f_y (ReH) = 300 MPa, but the tested yield strength shall not exceed f_y by more than the 90MPa and the ratio of tested ultimate strength, f_u (Re) to tested yield strength (f_y) shall be at least 1.25 and minimum elongation after fracture (A5.65) & minimum total elongation at maximum force (Agt) is 17% and 8% respectively.
Grade 400 (B 400DWR): Ribbed or Deformed bar produced and marked as per BDS ISO 6935-2:2016 with minimum yield strength, f_y (ReH) = 400 MPa, but the tested yield strength shall not exceed f_y by more than the 120MPa and the ratio of tested ultimate strength, f_u (Re) to tested yield strength (f_y) shall be at least 1.25 and minimum elongation after fracture (A5.65) & minimum total elongation at maximum force (Agt) is 17% and 8% respectively.
Grade 420 (B420DWR): Ribbed or Deformed bar produced and marked as per BDS ISO 6935-2:2016/ ASTM A706M - 16 with minimum yield strength, f_y (ReH) = 420 MPa but f_y (ReH) not exceeding 540 MPa, the ratio of ultimate tensile strength, f_u (Rm) to actual yield strength, f_y (ReH) shall be at least 1.25 and minimum elongation in 200mm shall be at least 14% for bar sizes 10mm through 20mm, at least 12% for bar sizes 22mm through 32mm and at least 10% for bar sizes 40mm and 50mm.
Grade 500 (B 500CWR): Ribbed or Deformed bar produced and marked as per BDS ISO 6935-2:2016 with minimum yield stress, f_y (ReH) = 500 MPa, the ratio of ultimate tensile strength, f_u (Rm) to actual yield strength, f_y (ReH) shall be at least 1.15 and minimum total elongation after fracture (A5.65) & minimum elongation at maximum force (Agt) is 14% and 7% respectively. [This reinforcement shall be selected as per instruction given in the drawing & after getting approval from Design unit, RHD.]
Grade 500 (B 500DWR): Ribbed or Deformed bar produced and marked as per BDS ISO 6935-2:2016 with minimum yield stress, f_y (ReH) = 500 MPa, but f_y (ReH) not exceeding 650 MPa, the ratio of ultimate tensile strength, f_u (Rm) to actual yield strength, f_y (ReH) shall be at least 1.25 and minimum total elongation after fracture (A5.65) & minimum elongation at maximum force (Agt) is 13% and 8% respectively. [This reinforcement shall be selected as per instruction given in the drawing & after getting approval from Design unit, RHD.]
Fusion Bonded Epoxy Coating Reinforcement (FBECR): Extra over reinforcing bar items as above for providing Fusion Bonded Epoxy Coating (FBEC) to reinforcement bars as per ASTM A775/ BDSISO 14654: 2013 specification for a coating thickness

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(after curing) of 175 to 300 microns for 10mm to 16mm and 175 to 400 microns for 20mm to 50mm re-bars including extra cost on account of careful handling during straightening, cutting, bending & placing, extra cost on account of using PVC coated binding wire instead of G.I. wire, extra cost on account of touch-up material (All cut edges/weld areas and bend locations where coating has been damaged touch up shall be done with same Coating, the upper thickness limit shall not apply to repaired areas of damaged coating) supplied by coating agency and repair work, extra cost on account of transportation to and fro from steel yard to plant and plant to work site by trailer (if required), loading, unloading, flexibility & holiday testing, etc. complete to ensure proper resistance of FBE against corrosive environment.

[Fusion Bonded Epoxy Coating to be proposed only in Coastal Area/Severe Exposure Condition with prior approval of Design Unit, RHD.]

5.2.2.2 Wire Mesh

Wire mesh shall conform to the requirements of AASHTO Standard Specification M 55 - Welded Steel Wire Fabric for Concrete Reinforcement.

5.2.2.3 Binding Wire

Reinforcement binding wire shall be best black annealed mild steel wire, approximately 1.6 mm in diameter. PVC coated binding wire instead of G.I. wire have to be used for FBECR as recommended by the FBECR manufacturer.

5.2.2.4 Bar Sizes

AASHTO Standard Specifications refer to the Imperial measurement system. However, metric sizes of steel are shown on the Drawings and shall be used.

5.2.2.5 Ordering Material

The name of the proposed supplier (or names of proposed suppliers) of the reinforcement shall be submitted as soon as possible to the Engineer for his approval. The Contractor shall also submit all relevant data on the steel required by the Engineer, such as breaking strength, yield strength, characteristics on elongation, chemical composition etc. Copies of orders placed shall be submitted to the Engineer.

Bar reinforcement shall be transported in standard bundles, tagged and marked in accordance with the Code of Standard Practice of the Concrete Reinforcing Steel Institute. No steel shall be delivered without a manufacturer's certificate guaranteeing the yield stress, which shall be submitted to the Engineer. The steel shall be stored on Site and marked in a way that later enables identification of the steel corresponding to each certificate.

5.2.2.6 Additional Tests

The Contractor shall cut out steel samples as directed by the Engineer and these shall be tested according to the Engineer's instructions by an approved Testing Institution. Expenses incurred for additional tests in connection with cutting out, transporting and testing of the samples shall be paid for by the Contractor. In general, two samples shall be tested from each batch of a particular size of reinforcement delivered to the site.

5.2.3 Construction Methods

5.2.3.1 Protection and Storage

Reinforcement for structures shall be handled and stored in a manner that will prevent bending out of the desired shape and any accumulation of dirt, oil and paint. When placed in the works it shall be free from dirt, oil, grease, paint, mill scale and loose or thick rust.

5.2.3.2 Cutting and Bending

Bars shall be cut and bent cold to the dimensions indicated and with equipment and methods approved by the Engineer.

Stirrups and tie bars shall be bent around a pin having a diameter not less than four times the minimum thickness of the bar. Bends for other bars, where full tension in the bar may occur, shall be made around a pin having a diameter not less than twenty times the bar diameter. Hooks shall conform to American Concrete Institute Standard Building Code Requirements for reinforced concrete ACI 318-83/ACI 318-19, or as shown on the Drawings.

5.2.3.3 Placing, Supporting and Fastening

All bar reinforcement shall be placed, supported and secured prior to any concreting operations. The reinforcement shall be checked and approved by the Engineer before pouring of concrete.

Cover blocks required for ensuring that the reinforcement is correctly positioned shall be as small as possible, consistent with their purpose, of a shape and material acceptable to the Engineer, and designated so that they will not overturn when the concrete is placed. If made of concrete, the maximum size of aggregate shall be 6 mm and the mix proportion shall be one part of Portland cement to 2 parts of sand by weight. Wire shall be cast in the block for the purpose of tying it to the reinforcement. The wire must not be closer than 30 mm from the concrete surface. The use of small stones or wood blocks shall not be permitted.

The reinforcement shall be held securely in place at the exact position and at the exact spacing as indicated on the Drawings by the use of wire ties at bar intersections, supports

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and cover blocks. Wire ties shall be securely tied and folded so that they do not project beyond the planes formed by the reinforcing bars. The adequacy of the supports and ties to secure the reinforcement properly shall be subject to the approval of the Engineer.

5.2.3.4 Splicing

Reinforcement shall be furnished in the lengths indicated on the Drawings. When the Contractor wishes to use more splices than are indicated and/or necessary, the Contractor shall furnish Working Drawings to the Engineer for approval in accordance with the guidelines provided on the Contract Drawings. If such additional splices are approved, the extra weight occasioned by such splices shall not be included in the measurement of reinforcement for payment.

All splices for high yield deformed steel bars and mild steel plain steel bars shall have lap lengths as shown on the Drawings. Lap splices shall generally be located at points of minimum tension in bars. Except where otherwise shown on the Drawings lap splices shall be made with the bars placed in contact and securely wired together.

Welding of reinforcing steel shall be done only if detailed on the Drawings or approved in writing by the Engineer. Before the Engineer may approve of such welding, the Contractor shall submit and test any samples as the Engineer may require and make due allowance for the time elapsing before results are available.

5.2.3.5 Substitutions

Substitutions of bars shall be permitted only with specific authorization by the Engineer and at the expense of the Contractor. If bars are substituted they shall have a cross sectional area equivalent to the design area, or larger. If substitutions of bars are permitted, the Contractor shall produce working drawings and reinforcing detailing at his own expense and to the approval of the Engineer.

5.2.4 Measurement

The quantity of reinforcement to be measured under this Section shall be the computed weight in tonnes of material used and accepted as shown on the Drawings provided that the quantity shall not include the reinforcement in any item of work for which the basis of payment includes the reinforcement. In computing the weight to be measured, the theoretical weights of bars of the cross section shown on the Drawings or authorized, shall be used. The weight shall be calculated based on a constant mass of 0.00785 kg/mm² per meter run.

The computed weight shall not include the extra material incurred when bars larger than those specified are used, or the extra material necessary for splices when bars shorter than those specified are used with the permission of the Engineer, or the weight of any devices

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used to support or fasten the reinforcement in the correct position including any necessary chairs.

However, payment shall be allowed for lap splices not shown when the bars are longer than 12 meters. Only one lap splice per every 12 meters will be paid for.

5.2.5 Payment

This work measured as provided above, shall be paid for at the Contract unit price per metric tonne of reinforcement of the particular type. The payment shall be full compensation for furnishing and placing reinforcement of any size and for all labor, binding wire, equipment, tools and incidentals necessary to complete the work prescribed in this Section.

Pay items shall be:

05/02/01	Mild Steel Reinforcing Bars	Tonne
05/02/02	High Yield Deformed Steel Reinforcing Bars	
05/02/02(a)	High Yield Deformed Steel Reinforcing Bars (Grade 300: 300 MPa)	Tonne
05/02/02(b)	High Yield Deformed Steel Reinforcing Bars (Grade 400: 400 MPa)	Tonne
05/02/02(c)	High Yield Deformed Steel Reinforcing Bars (Grade 420: 420 MPa)	Tonne
05/02/02(d)	High Yield Deformed Steel Reinforcing Bars (Grade 500CWR: 500 MPa)	Tonne
05/02/02(e)	High Yield Deformed Steel Reinforcing Bars (Grade 500DWR: 500 MPa)	Tonne
05/02/02(f)	High Yield Deformed Steel Reinforcing Bars (Grade 550: 550 MPa)	Tonne
05/02/02(g)	FBECR : Extra cost for FBEC over item 05/02/02(a) to 05/02/02(e)	Tonne
05/02/02(h)	For Re-bar diameter: 8mm to 12mm For Re-bar diameter: 16mm to 50mm	Tonne Tonne

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05/02/03	Wire Mesh Reinforcement	Tonne

5.3 PRESTRESSING REINFORCEMENT

5.3.1 Description

5.3.1.1 General

This work shall consist of the furnishing and placing, pre-tensioning or post-tensioning of bars, strands or wires as specified on the Drawings and these Specifications.

5.3.1.2 Definitions

Post tensioning is defined as any method of prestressing concrete in which the tensioned reinforcement is tensioned after the concrete is placed.

Pre-tensioning is defined as any method of prestressing concrete in which the tensioned reinforcement is tensioned before the concrete is placed.

Prestressing reinforcement is defined as any reinforcement to which prestress is applied by post tensioning or pre-tensioning.

Non-prestressing reinforcement (“ordinary reinforcement” or only “reinforcement”) is defined as any reinforcement to which no prestressing tension is applied externally.

5.3.2 Materials

5.3.2.1 Tendons for Post Tensioning Systems

Prestressing steel shall be Stress-Relieved Wire according to AASHTO M 204, Stress Relieved Strand according to AASHTO M 203 or High-Strength Steel bar according to ASTM A 722.

The Contractor may propose any other internationally acknowledged prestressing steel subject to approval of the Engineer. Detailed drawings showing the tendon arrangement and calculations shall be submitted, which verify that the proposed tendons introduce into bridge structures the prestressing effect equivalent to the original design shown on the Drawings.

No tendons shall be used in the construction before testing has been carried out and approved by the Engineer.

5.3.2.2 Anchorage Assemblies

The end anchorages (stressing anchorages and dead end anchorages) shall be especially designed for the actual type of tendon and must have been used on other similar work and thus have demonstrated proper functioning and durability for this purpose.

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Allowance shall be made to test anchorages to destruction. The anchorages shall be capable of fixing the prestressing steel at a load of not less than 95% of the specified minimum tensile strength of the prestressing steel.

The manufacturer shall submit appropriate test certificates from an approved testing laboratory.

Information on all details of the design and the steel quality of the anchorages shall be submitted to the Engineer.

5.3.2.3 Sheathing

All sheathing shall be of the metallic corrugated type, galvanized and fully mortar tight. The sheathings shall be strong enough to maintain their shape under such forces as may be expected to act on them.

All information on proposed sheathings shall be submitted by the Contractor to the Engineer for his approval.

All sheathing shall be of the metallic corrugated type, galvanized and fully mortar tight. The sheathings shall be strong enough to maintain their shape under such forces as may be expected to act on them. All information on proposed sheathings shall be submitted by the Contractor to the Engineer for his approval.

5.3.3 Construction Methods

5.3.3.1 General

The Contractor shall provide a technician skilled in the use of the actual system of prestressing to supervise the work to the satisfaction of the Engineer.

The Contractor shall provide all equipment necessary for the construction and the prestressing. Prestressing shall be done with approved jacking equipment. If hydraulic jacks are used they shall be equipped with accurate reading pressure gauges. The combination of jack and gauge shall be calibrated and a graph or table showing the calibration shall be furnished to the Engineer. Should other types of jacks be used, calibrated proving rings or other devices shall be furnished to accurately establish jacking forces.

If alternative systems are adopted, the Contractor shall submit, for the approval of the Engineer, drawings and calculations which show the arrangements of tendons, anchorage assemblies, etc. and verify that the prestress occurring at every section is equal to that produced by the system originally used in the design.

A) Pre-Tensioning Systems

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Prestressing strand and wire to precast piles shall be seven wire strand and wire in accordance with ASTM A 416-74.

Prestressing tendons can be directly substituted by other types of equivalent strength tendons conforming to JIS G 3109-1971, BS 3617-1971 and BS 2691-1969.

Certificates

Manufacturer's test certificate for breaking strength shall be obtained for each delivered coil or bundle and a stress/strain diagram shall be obtained for every fifth coil or bundle.

Each coil or bundle of prestressing steel shall be delivered with charge No. and markings to allow identification of the corresponding tests carried out.

Copies of the manufacturer's dated test certificates of his Routine Testing shall be submitted to the Engineer for his approval.

Tests

Tests in addition to those to be carried out by the manufacturer as specified herein will be required.

Supervised by the Engineer, the Contractor shall cut out samples (approximately 1.0m long) for each 25 tons of steel, or as directed by the Engineer. The breaking load, 0.2% proof load and elongation tests shall be carried out according to ASTM A 370, by an approved independent testing laboratory.

Expenses incurred in connection with cutting out, transport and testing of the samples shall be borne by the Contractor.

No tendons shall be used in the construction before the testing has been carried out and approved by the Engineer.

5.3.3.2 Storage of Materials

Coils and bundles of prestressing steel shall be stored flat on a floor raised off the ground and under full cover from the weather. They shall be protected from damage, oil, corrosion or any deleterious matter, and shall not be opened until required. Before being fabricated into prestressing tendons the strands or bars shall be cleaned of loose rust and any deleterious matter and inspected by the Engineer for approval. Prestressing steel reinforcement which shows signs of pitting or has any surface defects such as splits, roughness or necking is not to be used, and any lengths of wire or strand so affected shall be cut off and rejected.

Corrugated sheathing is to be delivered to the site coiled on to large diameter wooden drums, securely fastened and protected from damage. They shall be stored on site under cover from the weather, and shall be protected from rusting, damage, oil or any other

deleterious matter and shall be clean and free from all such matter before being used in the Works.

5.3.3.3 Manufacture of Tendons

Prestressing cables shall be prepared on site from coils of wires or strands. Tendons, which consist of a number of high tensile steel strands, shall be formed in a manner approved by the Engineer. In estimating the length of all cables, extra allowance must be made for applying either one or two tensioning jacks.

Sheathing shall be carefully examined prior to use and any damaged lengths shall be cut away and rejected.

Suitable spacers shall be provided, if required, to hold the strands or bars in correct position in the sheathings to ensure that there is sufficient space around each wire or cable to allow proper grouting.

Joints in corrugated sheathing shall be formed by the use of couplers and/or by wrapping the joints with tape. They shall be so designed as to prevent the ingress of concrete or other material during casting. All joints in sheathing shall be approved by the Engineer.

5.3.3.4 Placing Tendons and Sheathing

Tendons shall be carefully handled so as to avoid sharp bends or kinks. The sheathing and/or the tendon shall be rigidly supported in the exact positions as shown on the Drawings so that no movement can take place during casting of elements to be prestressed.

The tendons shall be placed with the following tolerances:

Vertical ± 10 mm, horizontal ± 20 mm.

The tendons shall be supported by special supporting arrangements as proposed by the Contractor and approved by the Engineer. If the sheathing is supported by reinforcement bars, they shall be plain round bars of mild steel. The supports shall be placed at adequate centres to ensure the tendons in all positions are placed along the prescribed curve. Care must be taken to prevent the supports from penetrating into the sheathings and if necessary special means must be used.

5.3.3.5 Placing Anchorages

Anchor cones, blocks and plates shall be positioned and maintained during concreting so that the centreline of the duct passes axially through the anchorage assembly.

All bearing surfaces of the anchorage shall be clean prior to concreting and tensioning. The anchorage itself shall be adequately protected against corrosion following the completion of the final stressing operation.

5.3.3.6 Jacks for Prestressing

All jacks used for prestressing shall be of the type applicable to the system adopted.

The accuracy of all load measuring equipment shall be checked to the satisfaction of the Engineer at the start of work each day it is to be used and whenever the equipment is moved to a different jack.

5.3.3.7 Post-tensioning Procedure

Prior to construction work, the Contractor shall submit a table which shows the tensioning order of all tendons to be tensioned at each construction stage, pressure of hydraulic jacks or pumps, anchor pull-in and elongation of each tendon. This proposed post-tensioning procedure is subject to approval by the Engineer. The Contractor shall carry out tensioning tests on a few tendons designated by the Engineer, and the results shall be taken into consideration for the table preparation. The result of the tensioning work for each tender shall be submitted in a form designated by the Engineer.

Tensioning shall be carried out only in the presence of the Engineer unless permission in writing has been obtained to the contrary.

Immediately before tensioning, the Contractor shall prove that all tendons are free to move between jacking joints and that members are free to accommodate the horizontal and vertical movements due to the application of prestress.

Unless otherwise described in the Contract, concrete shall not be stressed until it has reached at least the age at which two test cylinders taken from it attain the specified transfer strength. The test cylinders shall be made and tested in accordance with Section 5.1.2.4. The Contractor shall cast sufficient additional cylinders to demonstrate that the required strength of the concrete at transfer has been reached.

Where members consist of jointed elements, the strength at transfer of the jointing material shall be at least equivalent to the specified transfer strength of the member.

The Contractor shall establish the datum point for measuring extension and jack pressure to the satisfaction of the Engineer.

The Contractor shall add to the forces described in the Contract an allowance for anchorage friction and jack losses. The total forces and calculated extensions shall be agreed with the Engineer before stressing is commenced.

Immediately after anchoring, the stresses in the prestressing tendons shall not exceed 70% of their specified characteristic loads. During stressing the value shall not exceed 80%.

The tendons shall be stressed at a gradual and steady rate. The forces in the tendons shall be obtained from readings on two load cells or pressure gauges incorporated in the equipment. The extensions of the tendons under agreed total forces shall be within 5% of the agreed calculated extensions. If the required elongation cannot be reached, the jacking force may be increased to 80% of the specified characteristic load of the tension. If the difference between the measured and calculated elongation is more than 10%, however, no further tensioning shall be made until the calculations and the equipment is checked.

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- 1) When stressing tendons with stressing anchorage at both ends, the pull-in at the ends remote from the jack shall be accurately measured and the appropriate allowances made in the measured extensions at the jack ends.
- 2) When the prestressing has been applied to the satisfaction of the Engineer, the tendons shall be anchored. The jack pressures shall then be released in such a way as to avoid shocks to the anchorages or tendons.
- 3) If the pull-in of the tendons at completion of anchoring is greater than agreed by the Engineer, the loads shall be released at a gradual and steady rate and tensioning carried out afresh.
- 4) The Contractor shall keep full records of all tensioning operations including the measured extensions, pressure gauge or load cell readings and the amount of pulling at each anchorage. Copies of these records shall be supplied to the Engineer within 24 hours of each tensioning operation.

The men employed shall be experienced in this class of work. Every precaution shall be taken to ensure the safety of the workmen during the tensioning period.

5.3.3.8 Grouting

Grouting shall be carried out as specified in Section 5.1.3.17.

5.3.3.9 Finishing off Tendons

After grouting, the ends of the anchorages and any projecting ends of cut-off tendons shall be covered by concrete or special mortar mix.

5.3.3.10 Pre-Tensioning

The specified force shall be maintained by the use of fixing devices at the ends of the tensioning steel during concreting and curing until the concrete has attained the specified strength or other strength approved by the Engineer. The tensioning steel shall then be released gradually and uniformly.

All details and function of the “prestressing bed” shall be approved by the Engineer.

The amount of tensioning shall be as shown on the Drawings or as instructed by the Engineer.

The amount of jacking force and the elongation shall be measured on each strand wire or bar in a way approved by the Engineer.

Test specimens manufactured and cured in accordance with Section 5.1.2.4 may be requested for the verification of the concrete strength before releasing the tensioning steel.

5.3.4 Measurement

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The quantity to be measured shall be the theoretical weight in metric tons of the prestressing steel as shown on the Drawings without sheathings, anchorages etc., and measured between the outer faces of the anchorage blocks.

5.3.5 Payment

The work measured as provided above shall include all works as specified including provision of sheathings, anchorages, couplers, spirals, supports for the tendons, tensioning, grouting and finishing works.

Pay item shall be:

05/03/01	Prestressing Wire or Strand (as detailed on the Drawings)	Tonne

5.4 EXISTING CONCRETE

5.4.1 Description

This work shall consist of the construction of small extensions; reconstruction of localized defective concrete; rehabilitation of existing concrete facing; reinforcing, anchoring, tying and nominal stressing together of concrete elements; ground anchors; and sealing and treatment of structural cracks in various forms of members, all in accordance with these Specifications and the lines, levels, grades, dimensions and locations shown on the Drawings and as required by the Engineer.

5.4.2 Materials

5.4.2.1 Concrete

Concrete shall comply with the requirements of Section 5.1 of these Specifications.

5.4.2.2 Reinforcement

Reinforcement shall comply with the requirements of Section 5.2 of these Specifications.

5.4.2.3 Prestressing Reinforcement

Prestressing reinforcement shall comply with the requirements of Section 5.3 of these Specifications.

5.4.2.4 Cement Grout and Mortar

Cement grout and mortar shall comply with the requirements of Section 5.1 of these Specifications.

5.4.2.5 Resin Repair Mortars

Epoxy resins, unsaturated reactive polyester resins or unsaturated acrylic resins specified on the Drawings and detailed in the Bill of Quantities shall conform to the requirements of the Manufacturers recommendations or other suitable alternatives, subject to the approval of the Engineer, where it can be demonstrated that the proposed alternatives are at least equivalent to the materials proposed.

5.4.3 Construction Methods

5.4.3.1 General

The Contractor shall in due time and as soon as possible present and discuss his construction proposals and work programmers for nominal extensions to existing concrete structures; for implementing repairs to existing structural cracks in concrete structure; for implementing repairs to existing concrete surfaces and for the rehabilitation of existing defective concrete.

The details of Works shall cover the requirements specified on the Drawings and as directed by the Engineer at each location. The scope of new Works shall be as confirmed by the Engineer. The precise extent of all concrete extensions or repairs shall be jointly surveyed by the Contractor and the Engineer at the commencement of the Works and the locations of all extensions, repairs or strengthening shall be recorded and carefully marked in paint on each structure to permanently identify the Works to be implemented.

In locations where existing concrete sections are to be extended or joined, the existing concrete shall be carefully broken back at the locations where sections are to be joined. The breaking will be done to ensure the damage to existing concrete is the absolute minimum. Sufficient concrete will be removed to expose where appropriate the reinforcement of the existing section. Sufficient reinforcement will be exposed to enable additional reinforcement to be lapped to the existing steel. The reinforcement will be carefully cleaned and all loose concrete shall be removed. The existing concrete will be cleaned of all dust and a construction joint shall be prepared accordingly on the exposed face to ensure a good feature can be obtained between the new work and the existing concrete section. Concrete and reinforcement for the construction of the new section shall conform in all respects to Sections 5.1 and 5.2 respectively.

Defective concrete on the front face of substructure walls such as piers, abutments etc., particularly adjacent to the water line; and in soffits to beams, slabs and other

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superstructures; on the wet faces of main beams and other superstructures shall be carefully removed in a sequence and in accordance with the strict instructions of the Engineer. Such works shall be permanently supervised by a technical representative of the Engineer and the Contractor shall also ensure technical staffs are permanently available on the Site to receive specific instructions. The existing structural integrity of existing members shall not be impaired during this operation and the Contractor shall be fully responsible for ensuring strict procedures are followed. Defective concrete on main structural members shall be carefully and cleanly removed by manual methods using hammers and chisels to expose the main and secondary reinforcement. This reinforcement shall be carefully cleaned using wire brushes unless the Engineer gives alternative instructions. The concrete shall also be carefully broken back and the surface shall be cleaned of all dust and loose material. The removed defective concrete shall be replaced by a method proposed by the Contractor that shall be subject to the approval of the Engineer. In this respect, the Contractor shall propose and clearly demonstrate that the method he proposes to adopt is capable of giving a guaranteed facing of concrete that would be equivalent in all respects to the workmanship standards that would be accepted in new works. Depending on the extent of the repair works, sprayed concrete or gunite will be allowed provided acceptable procedures are proposed. Traditional formwork methods with “letter boxes” will also be allowed for large volume repairs.

Strategic structural cracks on highly stressed structural members such as shear cracks at scarf joints or shear cracks in beam webs shall be sealed by resin repair mortars. The Contractor shall ensure temporary access is provided to effectively implement critical repairs. The final decision of the repair resin will be made on completion of the inspection immediately prior to undertaking the sealing operation. Initially, cracks will be cleaned of all dust and debris in accordance with manufacturer’s recommendations once the resin to be adopted has been identified. Depending on the method to be adopted, nipples shall be inserted along the cracks or vacuum impregnation procedures shall be prepared to enable grout to be effectively injected into the structural cracks. The Engineer shall assess the effectiveness of crack repairs, generally on the basis of the quantity of resin injected.

Structural concrete members that exhibit cracking and relative movement may be anchored or tied in accordance with the Engineer’s instructions. Wing walls and abutments shall be tied and anchored at the locations and to the details indicated on the Drawings and as specified in the Bill of Quantities. Prior to commencing any of the work, the Contractor shall obtain the approval of the Engineer of the methods to be adopted for all temporary arrangements. This shall cover the provision of temporary stages; the proposed drilling methods; proposed safety measures; proposed anchoring methods and subsequent testing for ground anchors to ensure tie bars are capable of carrying twice working load; proposed stressing methods and ultimate grouting of anchor bars. The Contractor shall take

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instructions from the Engineer on the precise requirements for the provision; installation and anchoring of all tie bars incorporated in the Works.

5.4.3.2 Workmanship

Repairs and the like to existing concrete shall be constructed as shown on the Drawings or as may be required, by skilled and experienced personnel well versed in this type of work. The Contractor shall clearly demonstrate that his workforce proposed to be used on concrete repair works have a capability to complete this form of work to a satisfactory standard. Such demonstrations may take the form of pilot repair works not directly associated with the Works.

5.4.4 Measurement

Concrete Extensions and Repairs shall be measured in either cubic meters or square meters depending on the form of work ordered, placed and accepted. In computing quantities, the dimensions of concrete extensions where appropriately shown on the Drawings for new work and extensions shall be used as the basis for measurement. Remedial repairs of defective concrete face work and replacement of defective concrete shall be measured by the area of square meters ordered, marked up and accepted. The sealing of cracks with resin repair mortars shall be measured by the weight of resin used in the injection process of cracks ordered to be repaired, marked up and accepted. The sealing of cracks with cement mortar shall be measured by the cumulative length of cracks ordered to be repaired, marked up and accepted. The provision of tie bars and ground anchors, and installation (including fixing, drilling, grouting in stages, stressing etc.) shall be measured by the weight of bar ordered, installed and accepted.

No incidental works necessary to perform the repair works shall be measured; the Contractor shall include in the payment items for all necessary temporary works to undertake and complete every operation.

5.4.5 Payment

The Work measured as provided above shall be paid for at the Contract unit prices per cubic meter of concrete or square meter of concrete refacing. Resins used in cracks shall be paid for at the Contract unit prices per kg of material used. Anchor and tie bars shall be paid for at the Contract unit prices per tonne of bar used. Concrete cracks filled with cement mortar shall be paid for at the Contract unit prices per length of crack required. The rates shall be fully inclusive of all cost of all labor and materials temporary works and equipment to complete the works in a professional manner.

Pay items shall be:

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05/04/01	Modifications to Existing Concrete	Cubic Meter
05/04/02	Concrete Surface Repair Works (Superstructures)	Square Meter
05/04/03	Concrete Surface Repair Works (Substructures)	Square Meter
05/04/04	Resin Repair Mortars	Kg
05/04/05	Cement Mortar in Cracks	Linear Meter
05/04/06	Anchor and Tie Bars	Tonne

5.5 BRICKWORK

5.5.1 Description

This work shall consist of the construction, reconstruction, rehabilitation, face work repairs and repointing of brickwork structures, also the construction of brick drainage layers, in accordance with these Specifications and the lines, levels, grades, dimensions and locations shown on the Drawings or as required by the Engineer.

5.5.2 Material

5.5.2.1 Specifications for Materials

A) Bricks

First class bricks shall be made from good brick earth, free from saline deposits, and shall be sand-moulded. They shall be thoroughly burnt by coal without being vitrified, of uniform and good colour, shall be regular and uniform in size, shape and texture with sharp square edges and parallel faces. They must be homogeneous in texture and emit a clear metallic ringing sound when struck one against the other. They shall be free from flaws, cracks, chips, stones, modules of lime or kankar and other blemishes. A first class brick shall not absorb more than 1/6th of its weight of water after being soaked for one hour, and shall show no sign of efflorescence on drying. First class bricks not meeting these requirements shall not be used under any circumstances.

Jhama bricks are those which are so overburnt as to become vitrified or distorted, so as to be unsuitable for exact brickwork. Jhama bricks may be broken and used for aggregate in roadworks provided the vitrified mass has not become porous or spongy

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as a result of over burning and the aggregate satisfies the requirements of these Specifications.

Perforated bricks should be of uniform size and colour with sharp edges, square and parallel faces and have a standard number of perforations. They must be standard commercial products of approved manufactures and shall be approved by the Engineer.

Machine made pressed bricks shall be of the size shown on the Drawings and shall be standard commercial products of approved manufacturers. The use of machine made pressed bricks shall be approved by the Engineer prior to use in the Works.

First class bricks should have the following dimensions after burning: 242 mm × 115 mm × 70 mm. Picked Jhama bricks may have dimensions slightly below those for other brick but not less than 235 mm × 110 mm × 70 mm. The unit weight determined in accordance with STP 7.8.3 of 1st class bricks shall not be less than 1,100 kg/m³ and the unit weight of Jhama bricks shall not be less than 1,200 kg/m³.

The crushing strength of bricks shall be tested in accordance with STP 7.8.4. The average crushing strength of first class bricks shall not be less than 17 N/mm². The average crushing strength of Jhama Bricks shall not be less than 20 N/mm².

B) Cement

Cement shall be as specified in Section 5.1.

C) Fine Aggregate

Fine aggregate shall be as specified in Section 5.1. The fineness modulus of sand shall not be less than 1.50.

D) Water

Water shall be as specified in Section 5.1.

E) Steel Reinforcement in Anchors

Steel and anchorages shall be as specified in Sections 5.2 and 5.3.

5.5.2.2 Specifications for Mortar

Cement mortar shall consist of a mixture of one part by weight of cement to two parts by weight of sand. The cement and sand shall be mixed dry and in the specified proportion until the colour of the mixture is uniform. Approved water shall then be added sparingly, only the minimum necessary being used to produce a workable mixture of normal consistency. The water/cement ratio in no case shall exceed 50% by weight, or as directed by the Engineer. The mixing shall be done on a clean board or platform with tied joints, to avoid leakage. At the closing of each day's work the mixing trough and pans shall be thoroughly cleaned. Cement mortar shall be mixed in such quantities as can be used in the

work within 30 minutes. Mortar, which has taken initial set, shall not be used nor shall it be remixed with fresh mortar and such mortar shall be discarded and removed from the working site.

5.5.3 Construction Methods

5.5.3.1 General

The details of Works shall cover the requirements specified on the Drawings or as directed by the Engineer at each location. The scope of new Works shall be as indicated on the Drawings and as confirmed by the Engineer. The precise extent of all brickwork extensions, repairs to defective brickwork, rehabilitation of brickwork and repointing of mortar joints shall be surveyed by the Contractor and the Engineer at the commencement of the Works and the locations of all repairs shall be recorded and carefully marked in paint on each structure to permanently identify the Works to be implemented.

The Contractor shall in due time and as soon as possible present and discuss his construction proposals and work programme for building new brickwork structures; brickwork extensions to existing structures; brickwork repairs to defective bricks and rehabilitation of existing structures; and the repointing of defective joints in existing brickwork.

Excavations for new brickwork extensions such as wing walls shall be conducted to the requirements of Division 2. Blinding concrete shall be provided in accordance with the requirements of Section 5.1 Brickwork shall be constructed in accordance with the requirements specified hereunder, to the lines and levels on the Drawings and as directed by the Engineer.

Extensions to existing brickwork shall be achieved by the careful removal of existing skin courses as directed by the Engineer to the lines and levels specified and marked in paint. The old brickwork and joints shall be carefully prepared and cleaned to enable new brickwork to be constructed on and adjacent to the old courses.

Defective brickwork in the front faces of abutment walls, particularly adjacent to the water line, and in brick arches shall be carefully removed in a sequence as instructed by the Engineer. The existing stability of walls and arches shall not be impaired during this operation and the Contractor shall be fully responsible for ensuring that temporary supports are provided to guarantee that the full structural integrity of the walls, arches etc. is at all times retained. This may entail the temporary provision of struts and beams to existing arch rings, spandrel walls and retaining walls. The defective brickwork shall all be removed on an incremental basis if this is deemed desirable and new brickwork shall be carefully constructed to guarantee that the structural integrity of the element is returned to its original condition.

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Weak and defective mortar in existing brickwork shall be carefully removed from the joints to a depth instructed by the Engineer. The extent of mortar to be removed from existing joints shall also be instructed by the Engineer and shall be marked in point on existing brickwork faces. All joints shall be carefully cleaned prior to repointing with a cement mortar. The composition of the mortar will be as directed by the Engineer and will take into account the existing strength of joints that are not to be repaired. Existing joints shall be repointed in a workmanlike manner to ensure full depth penetration is attained and the finish is trimmed and flush with the face of the brickwork.

Cracks in existing brickwork shall be treated similarly to joints. Defective material shall be carefully removed, and the cracks shall be filled with cement mortar.

Tie bars and pattress plates shall be incorporated in accordance with the Drawings or the instructions of the Engineer, where existing brickwork can be effectively anchored to other structural features. Tie bars and pattress plates shall be painted in accordance with the requirements of these Specifications and shall be placed and positioned before brickwork extensions are commenced. This would be specifically appropriate for the strengthening and tying of brick spandrel walls to existing brick arches that are to be either elevated or extended. The anchors to the tie bars should be nominally tightened prior to the construction of the brickwork and subsequently nominally stressed after completion of the structural work and compaction of filling.

5.5.3.2 Workmanship

Brickwork shall be built plumbed, curved or battered as shown on the Drawings or as may be required, by properly supervised skilled masons and workmen. Bricks shall be cleaned and if necessary, they shall be scrubbed. Bricks shall be soaked in water for at least three hours before use.

Where new work joins previous work, the latter shall be well cleaned and thoroughly watered. All face work bricks shall be specially selected regarding size, shape and edges. Unless otherwise specified bricks shall be laid in English Bond, with frogs upward. All horizontal joints shall be parallel and level. Vertical joints in alternate courses shall come directly over one another. Joint thickness shall be 6 mm and shall in no case exceed 8 mm. The height of four courses, including 4 bed joints shall rise 300 mm. Walls shall always be carried up regularly along their entire length throughout the structure unless otherwise directed by the Engineer. The brickwork shall be cured for at least seven days. Fixtures such as clamps, pipe brackets etc. shall be provided in the brickwork during execution.

5.5.3.3 Brick Drainage Layers

Brick drainage layers to abutments, wing walls and other structures shall be constructed of “dry-laid” bricks as indicated on the Drawings and with vertical joints not exceeding a width of 10 mm.

5.5.4 Measurement

Brickwork shall be measured by the number of cubic meters that is ordered, placed and accepted. In computing quantities, the dimensions of brickwork shown on the Drawings for new work and extensions shall be used as the basis for measurement. Remedial repairs of defective brick and replacement of defective brickwork shall also be measured by the number of cubic meters ordered as indicated on the Drawings or marked up and accepted. No measurements will be taken on the defective brickwork that it is necessary to remove. The repointing of existing brickwork joints shall be measured by the number of square meters of repointing that is ordered, marked up and accepted. No measurements will be taken on the amount of defective mortar it is necessary to remove.

Tie bars and pattress plates indicated on the Drawings or ordered by the Engineer shall be measured by the Tonne.

No measurements will be taken of any temporary work.

5.5.5 Payment

The work measured as provided above shall be paid for at the Contract unit prices per cubic meter of brickwork or square meter of repointing.

The Contractor's rates shall include for all temporary measures to retain structural adequacy of an existing structure; all preparatory work in breaking out defective brickwork and removal of the same; for mixing mortar; for placing brickwork on/against prepared surfaces to the lines, levels as indicated on the Drawings or as instructed by the Engineer; for finished joints in a neat and professional manner. The Contractor's rates shall be fully inclusive of all cost of labor and materials in providing brickwork with sound mortar joints that will satisfy the structural criteria of the elements of the whole.

The Contractor shall be paid at the Contract unit rate for tie bars and pattress plates installed and accepted.

05/05/01	New and Extended Brickwork	Cubic Meter
05/05/02	Brick Drainage Layer	Cubic Meter
05/05/03	Replacement of Defective Existing Brickwork	Cubic Meter
05/05/04	Repointing of Existing Brickwork Joints	Square Meter

05/05/05	Steel Tie Bars and Pattress Plates	Tonne

5.6 PAINTING METAL STRUCTURES

5.6.1 Description

This work shall consist of, unless otherwise provided in the Contract, the preparation of the metal surfaces on existing structures, the application, protection and drying of the paint coatings and the supplying of all tools, tackle, scaffolding, labor and materials necessary for the entire work as shown on the Drawings.

5.6.2 Materials

5.6.2.1 General

All paints to be used for the painting system shall be obtained from one manufacturer. Paint shall be supplied in sealed containers of not more than 5 litres capacity and these shall be used in strict order of delivery. The paint shall be adequate in all respects for the intended purpose and shall be obtained from the manufacturer ready for the use specified.

Paint shall be stored in sealed containers in a lock-up store where it is not exposed to extreme temperature. Any special storage conditions recommended by the manufacturer shall be observed.

Paint not used within the shelf life period specified on the containers, or within 18 months of the date of manufacture, shall be replaced.

At the end of a working period, paint with a limited pot life or any two pack primers etc. shall be discarded. Other types of paint shall be returned to the store and kept in sealed containers.

5.6.2.2 Primer Coat

The primer coat of paint for metal shall be a red lead paint and shall conform to the AASHTO Specification for Red Lead Ready-Mixed Paint, M 72.

Red lead pigment in the dry form or as a paste in oil shall conform to ASTM D 83. The 97% grade shall be specified for dry pigment.

In mixing for paint, raw linseed oil (ASTM D 234) may be replaced with boiled linseed oil (ASTM D 260) to the extent of 50% of the total oil content.

The paint, preferably, shall be factory mixed. As an alternative the pigment shall be furnished in the form of red lead paste.

5.6.2.3 Undercoat

The undercoat shall be red lead paint as specified above, tinted light brown with lamp black in an amount not exceeding 1/32 kilogram per litre of linseed oil. Dry film thickness shall be 50 micron.

5.6.2.4 Finish Coat

The finish coat shall be as shown on the Drawings or as specified by the Engineer. It shall conform to one of the following AASHTO Specifications:

Foliage Green Bridge Paint M 67

1) Black Bridge Paint M 68

Aluminium Paint (Paste-Mixing Vehicle) M 69

White and Tinted Ready-Mixed Paint (Lead and Zinc Base) M70

5.6.3 Construction Methods

5.6.3.1 Cleaning of Surfaces

A) General

Surfaces of metal to be painted shall be thoroughly cleaned, removing rust, loose mill scale, dirt, oil or grease and other foreign substances. Unless cleaning is to be done by sand blasting, all weld areas, before cleaning is begun, shall be neutralized with a proper chemical, after which they shall be thoroughly rinsed with water.

Cleaning may be carried out by hand, mechanical means, chemically, sand blasting or by flame cleaning. The method used in any area shall be approved by the Engineer. Methods of cleaning are described as follows. All cleaning shall be approved by the Engineer before the application of any paint.

B) Hand Cleaning

The removal of rust, scale and dirt shall be done by the use of metal brushes, scrapers, chisels, or hammers or other effective means. Oil and grease shall be removed by the use of gasoline or benzene. Bristle or wood fibre brushes shall be used for removing loose dirt.

C) Mechanical Cleaning

Steelwork shall be mechanically cleaned using power driven tools such as carborundum grinding discs, chipping hammers and needle guns, followed by steel wire brushing, washing and dusting to remove all loosened material. Excessive burnishing of the metal through prolonged application of rotary wire brushes shall be avoided. Any visible peaks and ridges produced by the use of mechanical cleaning tools shall be removed.

D) Sandblasting

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The sandblasting shall remove all loose mill scale and other substances down to the bare metal. Special attention shall be given to cleaning of corners and re-entrant angles. Before painting, sand adhering to the steel in corners and elsewhere shall be removed. The cleaning shall be approved by the Engineer prior to any painting, which shall be done within 2 hours and before rust forms.

E) Flame Cleaning

Metal shall be flame cleaned in accordance with the following operations:

5.6.3.2 Number of Coats and Colour

All steel shall be painted with one prime coat, and with not less than two field coats. The thickness of the prime coat shall not be less than 75 microns and the total thickness of the two field coats shall not be less than 125 microns.

The colour shall be as specified or determined by the Engineer. The coats shall be sufficiently different in colour to permit detection of incomplete application.

5.6.3.3 Weather Conditions

Paint shall not be applied when the air is misty, or when, in the opinion of the Engineer, conditions are otherwise unsatisfactory for the work. It shall not be applied upon damp surfaces.

Material painted under cover in damp weather shall remain under cover until dry or until weather conditions permit its exposure in the open. Painting shall not be done when the metal is hot enough to cause the paint to blister and produce a porous paint film.

5.6.3.4 Mixing of Paint

Paint shall be factory mixed. All paint shall be re mixed before applying in order to keep the pigments in uniform suspension.

5.6.3.5 Application

A) General

Painting shall be done in a neat and workmanlike manner. Paint may be applied with hand brushes or by spraying except that aluminum paint preferably shall be applied by spraying. By either method, the coating of paint applied shall be smoothly and uniformly spread so that no excess paint collects at any point. If work done by spraying is not satisfactory to the Engineer, hand brushing shall be required.

B) Brushing

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When brushes are used, the paint shall be so manipulated under the brush as to produce a smooth, uniform, even coating in close contact with the metal or with previously applied paint, and shall be worked into all corners and crevices.

On all services which are inaccessible for paint brushes, the paint shall be applied by spraying or applied with sheepskin daubers, to ensure thorough covering.

C) Spraying

Power spraying equipment shall apply the paint in a fine, even spray without the addition of any thinner. Paint, when applied with spray equipment, shall be immediately followed by brushing when necessary to secure uniform coverage and to eliminate wrinkling, blistering and air holes.

D) Removal of Paint

If the painting is unsatisfactory to the Engineer, the paint shall be removed and the metal thoroughly cleaned and repainted.

E) Thinning Paint

Paint as delivered in containers when thoroughly mixed is ready for use. If it is necessary to thin the paint in order that it shall spread more freely, this shall be done only by heating in hot water or on steam radiators, and liquid shall not be added nor removed unless permitted by the Engineer.

5.6.3.6 Painting Galvanized Surfaces

For the purpose of conditioning the surface of galvanized surfaces for painting, the painting shall be deferred as long as possible in order that the surface may weather. Before painting galvanized surfaces they shall be treated as follows:

In 1 gallon of soft water dissolve 2 ounces each of copper chloride, copper nitrate, and sal ammoniac, then add 2 ounces of commercial muriatic acid. This should be done in an earthen or glass vessel, never in tin or other metal receptacle. Apply the solution with a wide flat brush to the galvanized surface, after which it will assume a dark, almost black, color, which on drying becomes a grayish film. The Contractor may propose any alternative process as a method of treatment subject to the approval of the Engineer.

5.6.4 Measurement

The quantity of work done under this section shall be measured in square meters to include all painting required on each structure or structural unit.

5.6.5 Payment

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Payment will be made for the work, materials, labor and equipment as detailed on the Drawings and as specified in the Bill of Quantities.

Pay item shall be:

05/06/01	Preparation and Painting of Existing Structures	Square Meter

5.6.6 Cold Galvanizing Compound for Galvanic Protection

5.6.6.1 General

This work shall consist of, unless otherwise provided in the Contract, the preparation of the metal surfaces on existing structures, the application, protection and drying of the coatings and the supplying of all tools, tackle, scaffolding, labor and materials necessary for the entire work as shown on the Drawings.

5.6.6.2 Materials

- Cold Galvanizing Compound is a metallic coating which contains 95% - 96% zinc (Dust) in its dry film.
- Dry galvanized film should not contain any toxic elements.
- Specific Weight of the compound should be 2.50 – 3,0 g/ml.
- Solid content should be 86% by weight ($\pm 1\%$) and 52% by volume ($\pm 1\%$) according to ASTM D1475.
- Temperature resistance of dry film should be minimum -40°C and maximum 650°C .
- pH resistance in atmospheric condition should be 4.5 pH to 10.5 pH.
- It must have excellent UV resistance capacity.

5.6.6.3 Construction Procedure:

a) Preparation of the Surface:

Surface of the metal to be coated shall be thoroughly cleaned. Cleaning will be done with appropriate power tools or Green Rust Converter or blasting method. Before coating the rich, zinc product, cleaning and blasting must be done according to SA -1, SA- 2, SA- 2.50, SA- 3.00 (Swedish standard internationally recognized surface preparation method) ISO – 8501.

- i. SA – 1, Light blast cleaning: Through this process of cleaning, there it could be done 20 micron to 39 micron thickness of coating.
- ii. SA – 2, Thorough blast cleaning: Through this process of cleaning, there it could be done 39 micron to 59 micron thickness of coating.

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- iii. SA – 2.50 Very thorough blast cleaning: Through this process of cleaning, there it could be done 60 micron to 99 micron thickness of coating.
- iv. SA – 3.00 Blast to visually clean steel: Through this process of cleaning, there it could be done 100 micron to 360 micron thickness of coating.

Surface Cleaning could be done in three (3) ways.

- 1) With appropriate power tools & Green rust Converter.
- 2) Wet vapor blasting (Dustless)
- 3) Abrasive grit blasting or sand blasting.
 - a) **New metal surface:** Steam clean or high pressure wash-down all surface, followed by using appropriate power tools or Green rust converter or a grit slurry vapor blasting to obtain the roughness.
 - b) **Old, previously galvanized, painted or rusty surface:** Steam clean to remove all contaminations from porous surfaces. Allow to dry off and blast clean as normal.
 - c) **Galvanized steel in good condition:** Steam clean the surface, followed by a light sweep blast to remove the zinc salt layer.

5.6.6.4 Application of Cold Galvanizing Compound:

- a) Apply the content of Cold Galvanizing Compound as soon as possible on the prepared metal surface before any contamination or corrosion occurs before coating. Otherwise, the surface must be prepared again. The stipulated time for coating is within 2 (two) hours after completion of the blasting and cleaning.
- b) It can be applied on a clean surface by roller, brush and conventional spray gun or by airless spray.
- c) **Stripe coat:** It is always recommended to treat corners, sharp edges, nuts and bolts before applying a uniform coat by brush.
- d) **Stirring:** It must be thoroughly mechanically stirred to achieve a homogeneous liquid before application. After a maximum of 20 minutes, re-mixing is necessary.
- e) **Cleaning:** Before and after using the spraying equipment, it must be rinsed with fresh thinner. Brushes and rollers should also be rinsed with thinner. Never use white spirit.
- f) **Dilution:** For Brush or roller, use 5% Mineral Spirit or Aromatic hydrocarbon/appropriated thinner to dilute the content. For conventional spray, use 15% Mineral Spirit or Aromatic hydrocarbon/appropriated thinner to dilute the content. For Airless spray, use 7% Mineral Spirit or Aromatic hydrocarbon/appropriated thinner to dilute the content.
- g) **Application:** Once thoroughly mixed, the content can be applied by using a normal paint-brush, a short-fiber roller (not for first coat) or a conventional spray-gun or

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an airless spray-gun. When applying contents by spraying it must only be thinned by Mineral Spirit or Aromatic hydrocarbon/appropriate thinner.

- h) Temperature: The application surface temperature range is from 150C to 600C, where condition allows with a maximum humidity of 97%. Like all coatings the substrate surface should be free from all types of contamination.
- i) Reloading: When a new coat is applied on to an existing layer to form a single homogeneous layer, the old layer does not need to be removed before re-coating with a new layer. A removal of contamination is required though.
- j) Drying time: The content of film galvanizing system should be touch dry and dust free in about 10 (ten) minutes at 200C (40 micron DFT).

5.6.6.5 Measurement

- a) The quality of work done under this section shall be measured in square meters to include all coatings of Cold Galvanizing Compound required on each structure, structural unit and all components.
- b) For thickness measurement Digital coating thickness gauge shall be used.

5.6.6.6 Payment:

Pay Item shall be

05/06/02	40 Micron Cold Galvanizing Compound for minimum 10 years protection against rust and corrosion	Sqm
05/06/03	60 Micron Cold Galvanizing Compound (Duplex) including Polyurethane (PU) or Urethane or Polysiloxane continued with Micaceous Iron Oxide (MIO), Aluminum and Magnesium Silicate for minimum 13 years protection against rust and corrosion	Sqm
05/06/04	60 Micron Cold Galvanizing Compound for minimum 13 years protection against rust and corrosion.	Sqm
05/06/05	80 Micron Cold Galvanizing Compound for minimum 15 years protection against rust and corrosion	Sqm
05/06/06	100 Micron Cold Galvanizing Compound for minimum 18 years protection against rust and corrosion	Sqm
05/06/07	120 Micron Cold Galvanizing Compound for minimum 20 years protection against rust and corrosion.	Sqm
05/06/08	140 Micron Cold Galvanizing Compound for minimum 23 years protection against rust and corrosion.	Sqm
05/06/09	160 Micron Cold Galvanizing Compound for minimum 26 years protection against rust and corrosion	Sqm
05/06/10	180 Micron Cold Galvanizing Compound for minimum 30 years protection against rust and corrosion	Sqm

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05/06/11	360 Micron Cold Galvanizing Compound for minimum Life time protection against rust and corrosion.	Sqm

Note: There is data on the life expectancy of G60 hot-dip galvanizing in the specific environment in question, then an application of Cold Galvanizing Compound to a minimum dry film thickness of 3.0 mils or 80 Micron, in the same environment, will give the same life expectancy of the G60 hot-dip galvanizing.

5.7 BRIDGE STEELWORK

5.7.1 Description

This work shall consist of the carriage of unit bridging, steel beams/ girders and other items of bridge steelwork and ancillaries from a port to the bridge site, storage on site and installation/erection in accordance with the manufacturer's standard procedures or as shown on the Drawings.

Elastomeric bearings for composite bridge construction, materials for temporary works and other ancillary materials shall be provided by the Contractor.

5.7.2 Materials

Materials provided to the Contractor shall be collected by him from the port. The Contractor shall meet any demurrage costs at the port arising from his failure to provide the requisite loading equipment and/or transport. The Contractor shall exercise great care in loading, transporting, unloading, storing and installation/erection of all components. Any damage shall be repaired by the Contractor at his expense and to the satisfaction of the Engineer. If any component is damaged beyond repair, the Contractor shall bear all direct and indirect costs associated with replacement. Similarly, the Contractor shall make good any shortfall due to loss or theft.

The Contractor shall submit detailed proposals of elastomeric bearings for composite bridges to the Engineer, for approval, prior to procurement. The proposals shall be based on the design requirements and dimensions indicated on the Drawings.

Other materials for the permanent works provided by the Contractor shall be of the quality and type shown on the Drawings, subject to the approval of the Engineer.

5.7.3 Construction Methods

5.7.3.1 Unit Bridging

Unit bridging shall be assembled and installed by the Contractor in accordance with the standard procedures provided by the manufacturer. Bearings for unit bridging shall be installed in accordance with the Drawings and the manufacturer's instructions.

The method of erection shall be subject to the approval of the Engineer.

If the bridging is to be erected by cantilevering, the Contractor will be responsible for providing any necessary kentledge, rails for access and any other materials required for temporary works.

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If the bridging is to be erected in position on wooden bullah trestles, these shall be designed and constructed to provide the necessary rigidity and to support the loads without settlement or deformation. The Contractor shall submit detailed drawings and designs for the proposed trestles and false works to the Engineer for his approval. The Engineer's approval shall not, however, relieve the Contractor of his responsibility for ensuring the adequacy of his proposals and for the successful erection of the bridging.

When bridge parapet steelwork consisting of posts and barrier is provided with unit bridging, the fixing to reinforced concrete deck slabs shall be in accordance with the manufacturer's recommendations. The Contractor shall however submit his proposals for installation to the Engineer, for approval, prior to installation.

5.7.3.2 Steel Beams/ Girders for Composite Bridges

The Contractor shall submit proposals for the installation of elastomeric bearings and steel beams/ girders as shown on the Drawings to the Engineer for approval.

5.7.4 Measurement

Carriage of unit bridging, steel beams and other items of bridge steelwork and ancillaries from the port to site shall be measured by the tonne.

The fixing of bearings for unit bridging which are supplied to the Contractor shall be measured by number. The supply and fixing of elastomeric bearings for composite bridge construction shall be measured by number.

The assembly and installation of unit bridging shall be measured by the linear meter of bridge. Parapet steelwork fixed to reinforced concrete deck slabs shall be measured by the linear meter of parapet.

The installation of steel beams/ girders for composite bridge construction shall be measured by the tonne

5.7.5 Payment

Payment for carriage of bridge steelwork and ancillary items shall include for all materials, labor and equipment for loading at the port, transporting and unloading at the site.

Payment for the fixing of bearings for unit bridging and the supply and fixing of elastomeric bearings for composite bridge construction shall include the provision of all additional materials such as shims and mortar and the provision of all labor and incidentals to complete the work.

The Contractor's rates for the assembly and installation of unit bridging and steel parapet shall include all labor, temporary works and equipment required to complete the work.

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The Contractor's rate for the installation of steel beams and ancillary steelwork items for composite bridge construction shall include all labor, temporary works and equipment required to complete the work.

Pay items shall be:

05/07/01	Carriage of Bridge Steelwork from Port to Site	Tonne
05/07/02	Fixing of Bearings for Unit Bridging	Number
05/07/03	Supply and Fixing of Elastomeric Bearings for Composite Bridge Construction	Number
05/07/04	Assembly and Installation of Unit Bridging	Linear Meter
05/07/05	Installation of Steelwork for Composite Bridge Construction	Tonne
05/07/06	Installation of Steel Post and Barrier Parapet to Reinforced Concrete Deck Slab	Linear Meter

5.8 MOVEMENT JOINTS

5.8.1 Description

This work shall consist of furnishing and installation of materials for expansion joints in reinforced concrete structures and the furnishing and installation of fabricated bridge deck joints.

All expansion joints shall be products which have a proven successful performance record. The contractor shall submit for the approval of the engineer full details of the proposed joints. This shall include lists of projects in which the proposed product has been incorporated in similar structures and climatic conditions. The contractor shall submit substantiating information on previously installed units of the same type supporting the durability and periods free of maintenance claimed by the manufacturer.

The Design of the joint system shall facilitate inspection and replacement. Epoxy nosing joints shall not be permitted.

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- a) The Contractor shall furnish and install bridge deck expansion joints and accessories as shown on the Drawings or directed by the Engineer. The accessories shall include bolt assemblies, welding, metal work, elastomers and sealants as required.
- b) Should the proposed deck joints require changes to the basic concrete outline of the bridge decks, the Contractor shall also submit all relevant details to the Engineer for approval.

Grout or dry pack concrete for metalwork shall be mixed in the proportions and to the consistency approved by the Engineer. The Contractor shall furnish all cement and fine aggregate for grout or dry pack complying with the requirements of Section 5.1.2.1 (A) and Section 5.1.2.1(D). The cost of all work in connection with the grouting or dry packing operations and the cost of the cement and fine aggregate for grout shall be included in the rates tendered in the Bill of Quantities for furnishing and installing the various items of metal work for which the grout or dry pack is required. Before placing grout or dry pack, the surfaces of existing concrete on which the grout or dry pack will be placed shall be roughened and shall be cleaned of all laitance, loose or defective concrete, coatings and other foreign material by effective means followed by thorough washing. Such surfaces shall be kept moist immediately prior to the placing of the grout or dry pack.

5.8.2 Materials

5.8.2.1 Expansion Joints

The materials for expansion joints will be as detailed on the Drawings. Typically these will include compressible joint filler board, dowel bars and two part polysulphide sealant. Ancillary materials necessary for use with polysulphide sealant, such as primer and bond breaker tape shall be provided in accordance with the sealant manufacturer's recommendations. The Contractor shall obtain the Engineer's approval of all proposed materials prior to procurement.

5.8.2.2 Bridge Deck Joints

These shall be fabricated in accordance with the details shown on the Drawings. The Contractor shall obtain the Engineer's approval of any fillers and paints necessary to complete the joints, prior to procurement.

5.8.2.3 Joint Performance Requirements

- a. The joints shall be completely watertight. Special attention shall be paid to the detailing to ensure full water tightness at the faces of the parapets.
- b. All metal work shall be galvanized in accordance with Standard Drawing.

The movement capacity of deck expansion joints shall be as shown on the

Drawings.

5.8.2.6 Recommendation type for Expansion Joint

Following types of expansion joint can be recommended as per requirement of expansion or contraction amount:

SL.	Expansion or Contraction amount	Expansion Joint
1.	Less than 25mm	Angle Plate Type Joint
2.	25mm to 50mm	Elastomeric Single Strip Seal
3.	More than 50mm but less than or equal to 125mm	Finger Type Expansion Joints with drainage seal
4.	More than 125mm	Modular Sealed Expansion Joint

5.8.2.7 Measurement

Expansion joint shall be measured by the linear meter of complete joint installed, measurement being along a straight line from base to top of a wall or one side of a slab to the other, etc. The measured length may therefore include a sealant length of over twice this value if several faces of the concrete are sealed. Bridge deck joints shall be measured by the linear meter of joint installed.

5.8.2.8 Payment

Expansion joints measured in accordance with section 2.6 shall be paid for at the contract unit prices for providing joints in the locations indicated on the Drawing and described in the Bill of Quantities. Payment shall be full compensation for furnishing and installing all materials, including all labor, tools, equipment and incidentals necessary to complete the work.

Bridge deck joints measured in accordance with Section 2.6 shall be paid for at the Contract unit price. Payment shall be full compensation for furnishing all materials, fabrication either on or off site and labor, tools, equipment and incidentals necessary to complete the work shown on the Drawings.

Pay items shall be

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5/8/1	Expansion Joint Complete as Detailed on the Drawings in the Location Described in the bill of Quantities	Linear Meter
5/8/2	Bridge Deck Joint Complete as Detailed on the Drawings	Linear Meter

Materials shall comply with the following or equivalent as agreed with the Engineer:

- a) Structural Steel - BS4360
- b) Fixing to Bridge Structure - HSFG bolts to BS 4395
- c) Elastomer - similar to elastomeric bridge bearing

Exposed steel plate shall have a 2 mm non-skid surface coating in accordance with the manufacturer's recommendations, details of which shall be submitted to the Engineer.

5.9 DRAINAGE OF STRUCTURES

5.9.1 Description

This work consists of furnishing and erection of drain outlets on bridge decks and drainage of other structures including PVC piping, cleaning boxes, catch basins, concrete drains, erosion protection, inserts, fittings and other incidental parts necessary to provide for further supports of drain pipes in accordance with the lines, levels, grades, sizes, dimensions and types shown on the Drawings.

5.9.2 Materials

5.9.2.1 Bridge Gullies

The size and strength of bridge gullies shall be as indicated on the Drawings.

5.9.2.2 Cast Iron Piping

Cast Iron Piping shall comply with AASHTO Standard Specification M129 or other approved standards.

5.9.2.3 PVC Pipes

All PVC pipes shall comply with ISO R 161 "Pipes of Plastic Materials for the Transport of Fluids", or with BS 3505 "Unplasticized PVC Pipes for Cold Water Services".

5.9.2.4 Cleaning Boxes

The Contractor shall submit to the Engineer for his approval details of boxes with cleaning lids made of approved material to be installed in the locations indicated on the Drawings.

5.9.2.5 Catch Basins

To comply with Section 6.3 of these Specifications.

5.9.2.6 Culvert Pipes

To comply with Section 6.2 of these Specifications.

5.9.2.7 Inserts

Inserts shall be made of steel conforming to AASHTO Standard Specification M 183 (ASTM A 36).

5.9.2.8 Fittings and Other Incidentals

Materials should be as indicated on the Drawings or as approved by the Engineer.

5.9.3 Construction Methods

5.9.3.1 Storage and Handling of Materials

The steel and PVC parts shall be carefully handled and stored under cover on blocking, racks or platforms so as not to be in contact with the ground and the steel parts shall be protected from corrosion. Materials shall be kept free from dirt, oil, grease and other foreign matter.

5.9.3.2 Bridge Gullies

Bridge gullies are to be cast into the structure at the location as indicated on the Drawings. Special care must be taken to avoid displacement of gullies during concreting operations.

5.9.3.3 Cast Iron Piping

Special jointing instructions relevant to the purchased types of pipe will be issued by the Engineer. The pipes shall be embedded in the locations as indicated on the Drawings. During casting of concrete, the piping shall be kept in the correct position by means approved by the Engineer.

5.9.3.4 PVC Pipes

The jointing shall be of the type recommended by the manufacturer of the pipes. Bends shall be of long sweep, free from kinks. Embedded pipes shall be cast into the structure in

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the locations as indicated on the Drawings. During casting of concrete, the piping shall be kept in the correct position by means approved by the Engineer.

Exposed pipes shall be parallel to or at right angles to walls, slabs and girders. All exposed pipes shall be attached to concrete, steel, masonry or timber by galvanized malleable iron or galvanized steel straps, clamps or hangers of an approved type, held at not less than two points by galvanized steel bolts or lag screws. The runs shall be supported at not greater than 1 meter centers on horizontal or near horizontal runs, unless otherwise specified and not less than 50 mm clear of the supporting members.

All ends of pipes installed during construction shall be closed against the intrusion of foreign material.

5.9.3.5 Cleaning Boxes

To be installed by methods proposed by the Contractor and approved by the Engineer.

5.9.3.6 Catch Basins

To comply with Section 6.3 of these Specifications.

5.9.3.7 Culvert Pipes

To comply with Section 6.2 of these Specifications.

5.9.3.8 Weep Holes

While constructing abutment, wing wall and return wall weep holes shall be provided therein unless shown otherwise in the relevant drawings and filter layer approximately 1m wide right up against the wall to its full height shall be provided. Unless otherwise shown the weep holes shall be of concrete pipe of 100 mm diameter and shall extend through the full width of the wall with slope of about 1 vertical to 20 horizontal towards the drawing face. The spacing of weep holes shall be generally 1.5 m in either direction and shall be staggered. The lowest ones shall be located at about 300 mm above the low water level or ground level whichever is higher, or as directed by the Engineer. In general, one weep hole per 1.5 square meter of vertical surface shall be provided.

5.9.3.9 Inserts

To comply with Section 5.10 of these Specifications.

5.9.4 Measurement

The individual items shall not be measured and will be paid for as a lump sum.

5.9.5 Payment

Drainage work to a particular structure or to several structures, as defined in the Bill of Quantities, will be paid for at the Contract lump sum price.

The price and payment shall constitute full compensation for furnishing all materials as indicated on the Drawings including delivery, erection, surface treatment and finishing and for all labor, equipment, tools and incidentals necessary for the completion of the work.

The payment of Catch Basins and Culvert Pipes shall be paid within Sections 6.3 and 6.2 respectively.

05/09/01	Provision and fixing of drainage to structure(s) as detailed on the Drawings and defined in the Bill of Quantities	Lump Sum

5.10 INSERTS AND FITTINGS IN STRUCTURES

5.10.1 Description

This work consists of furnishing and embedding of inserts, fittings and other incidental parts into bridgeworks necessary to provide for further supports for utility pipes and cables and the like. The type, size and location will be indicated on the Drawings, or instructed by the Engineer.

5.10.2 Materials

Unless otherwise indicated on the Drawings, the inserts shall be made of steel conforming to AASHTO Standard Specification M 183 (ASTM A 36). Material to be as indicated on the Drawings or as approved by the Engineer.

5.10.3 Construction Methods

The inserts and fittings shall be embedded at the locations indicated on the Drawings or as instructed by the Engineer. During casting of concrete in structures, the inserts and fittings shall be kept in the correct position by means approved by the Engineer.

The inserts and fittings shall be plugged or pressed against the formwork in a way that no mortar from the concrete may enter the thread of the inserts or fittings.

After removal of the formwork, the Contractor shall clean the surface of the insert and fittings to the approval of the Engineer.

5.10.4 Measurement

The individual items shall not be measured and will be paid for as a lump sum.

5.10.5 Payment

This work will be paid for at the Contract lump sum price, which shall be fully inclusive of all working drawings, materials, installation including labor, equipment, tools and incidentals necessary to complete the work.

Pay item shall be:

05/10/01	Embedment of Inserts and Fittings	Lump Sum

5.11 BRIDGE BEARINGS (ELASTOMER)

5.11.1 Descriptions

This work shall consist of furnishing and installation of elastomeric bearings. Elastomeric bridge bearing shall be manufactured and furnished in accordance with this Specifications and Drawings and shall be installed at the locations shown on the Drawings or directed.

Throughout this Section the term 'elastomeric bearing' shall refers to a rubber bearing consisting of one or more vulcanized natural rubber slabs bonded to metal plates to form a sandwich arrangement and caters for translation and / or rotation of infrastructure by elastic deformation of elastomer.

5.11.2 Materials

5.11.2.1 Elastomer

The raw elastomer shall be virgin neoprene. Natural rubber shall comply with AASHTO M251-92. The elastomer compound whose nominal hardness falls within the ranges of 46-55, 56-65 and 66-75 are classified as types A, B and C, respectively. The elastomer compound shall meet the minimum requirements of table 5.11.2.3 when test specimens are cut from the finished product, the physical properties shall be permitted to vary from those specified in table 5.11.2.3 by 10 %

5.11.2.2 Steel Laminates

Steel laminates used for reinforcement shall be made from rolled mild steel conforming to ASTM A36 or A570 or A1011 High strength low alloy sheet (HSLA), Grade 36 or ASTM A1008/A1008M, Grade 40. The laminates shall have a minimum nominal thickness of 16 gages. The steel plates separating the elastomeric layers will be completely bonded by vulcanization to the elastomeric material on all surfaces using special metal-to-rubber bonding adhesive.

5.11.2.3 Bond

The vulcanized bond between fabric and reinforcement shall have a minimum peel strength of 5.2KN/m. Steel laminated bearings shall develop a minimum peel strength of 6.9 KN/m². Peel tests shall be performed by ASTM D429-14(2023) Method B.

Table 5.11.2.3

Test Method	Properties of Elastomer	Unit	Type A	Type B	Type C
D2240-15(2021) ASTM D412-16(2021)	Physical Hardness (shore a Durometer)	IRHD	50+5	60+5	70+5
	Minimum Tensile Strength	N/mm ² /MPa	15.52	15.52	15.52
	Minimum Ultimate Elongation		400	350	300
D573	Accelerated Ageing (70 hours at 100 dc +1dc)	IRHD	15	15	15
	Maximum Change in Durometer	%	-15	-15	-15
	Hardness	%	-40	-40	-40
	Maximum change in Tensile strength				
	Maximum change in Ultimate elongation				

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Test Method	Properties of Elastomer	Unit	Type A	Type B	Type C
D395-18(2025) Method B	Compression set 22 Hours @100dc, Maximum	%	35	35	35
D1149	Ozone Resistance Test after 100 hours at 100 pphm ozone in air by volume, 20% strain, 38dc +1dc		No Cracks	No Cracks	No Cracks
ASTM D297-21	Ash Content	%	5	5	5
ASTM D4014-23	Shear Modulus of Elasticity Minimum value Maximum Value	MPa	0.8 1.2	0.8 1.2	0.8 1.2

5.11.3 Fabrication and Installation

5.11.3.1 General

Bearing with steel laminates shall be casted as a single unit in a mould and vulcanized under heat and pressure. Casting of elements in separate units and subsequent bonding shall not be permitted, nor shall cutting from larger size cast be permitted.

Bearing of similar size to be used in particular bridge shall be produced identical process and in one lot as far as possible. Phased production only resorted to when the total number of bearings is large enough.

The moulds used shall be sand blasted, clean of all mill scales and shall be free from all contaminations prior to bonding by vulcanization. Rusted plates with pitting shall not be used. . All edges of plate shall be rounded.

Spacers used in moulds to ensure cover and location of laminates shall be of maximum size and number practicable. Care shall be taken to ensure uniform vulcanizing conditions and homogeneity of elastomer through the surfaces and body of bearings.

5.11.3.2 Fabrication tolerances

Laminated bearings shall be built to the specified dimensions within the following tolerances and should comply with AASHTO M251-92.

1. Overall Height	
Design thickness 32mm or less	-0, +3mm
Design thickness over 32 mm	-0, +6mm
2. Overall horizontal Dimensions	-0, +6mm
3. Thickness of Individual Layers of Elastomer	+/-20% of design value, Max+/- 3mm
4. Edge cover	-0, +3mm
5. Thickness of Top and Bottom cover layer	-0, smaller of 1.5mm and 20% of nominal cover layer thickness
6. Position of Exposed Connection Members	-0, +3mm
7. Parallelism with opposite Face	
Top and Bottom	1 in 200
Sides	1 in 50

5.11.3.3 Permission for fabrication

At least 30 days before manufacture of the bearings is commenced, the Contractor shall submit, for approval, certificates of tests performed on natural rubber to be used in the bearings. The tests shall be in accordance with AASHTO M251-92.

Manufacture of the bearings shall not commence until the Contractor has received preliminary approval of these details.

5.11.3.4 Testing facilities for fabrication

The manufacturer shall have his plant for all the test facilities required for the process and acceptance control tests. The test facilities and their operation shall be open to inspection by the Engineer on demand. Acceptance testing shall be commenced with the prior submittal of testing program by the manufacturer to the Engineer and after obtaining his approval. The Contractor shall inform the Engineer at least one month in advance of the date and place of manufacture and test facilities of the bearing. The Contractor shall make necessary arrangement for the Engineer to inspect the manufacturing process of tests. If the place of manufacture or testing is located overseas, the Contractor shall allow the cost for all expenses incurred by two officers nominated by the Employer for the inspection and testing of bearings. The Contractor shall provide the Engineer with all facilities at the places of manufacture and necessary for such inspection.

5.11.3.5 Quality control certificate

A lot under acceptance shall comprise all bearings, including a pair of extra test bearings of equal or nearly equal size produced under identical conditions of manufacture to be supplied for a particular project. The manufacture shall certify for each lot of bearing under acceptance:

That an adequate system of continuous quality control was operated in his plant

That the entire process remained in control during the production of the lot of bearings under acceptance as verified from the quality control records /charts which shall be open to inspection of the Engineer on demand.

A certified copy of results of process control testing done on samples of elastomer used in the production of the lot shall be appended and shall include at least the following information.

Composition of the compound-raw elastomer and ash content, the grade of raw elastomer used (including name, source, age on self). Test results of hardness, tensile strength, elongation at break, compression test, accelerated ageing etc.

An information card giving the details for the bearings duly certified by the manufacturer shall be appended.

The manufacturer of the bearings shall have not less than 5 (five) years successful experience in manufacturing similar type and capacity bearings.

5.11.3.6 Sample Testing of Bearings

- a) No bearings shall be installed until tests in accordance with AASHTO M251-92 have been completed by an approved laboratory on randomly selected bearings and the bearings, having achieved all requirements, have been approved.

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- b) Bearings for testing shall be selected by the Engineer and the Engineer shall be present at any testing. The rate of testing of bearings shall be in accordance:

Bearing	Rate of Testing
Type A	1 in 4

- c) Each bearing shall be indelibly marked with white paint with an identifying number as directed by the Engineer on the side. This number shall be the bearing identification number for test certificates.

Any bearing which fails to pass these requirements shall be indelibly marked 'FAILED' and shall not be used in the works. 'FAILED' bearings will not be paid for.

- d) Each bearing which passes these tests and complies with this Specification in all other respects shall be indelibly marked 'PASSED'.
- e) The Contractor shall submit, for approval, a copy of a test certificate giving test results of the bearings which have passed the tests.
- f) Notwithstanding anything to the contrary contained in this Specification, the inspection, examination and testing of bearing samples by the Engineer and any consent to proceed with the manufacture of the bearings resulting from such acts shall not prohibit the Engineer from making further inspection, examination, or tests on the bearings subsequently and rejecting any bearings if shown to be in non-compliance with this Specification. The Engineer may reject any bearing with flaws or irregularities.

5.11.4 Installation

5.11.4.1 Cement Mortar Bearings pad

The cement mortar shall have a minimum compressive strength at 7 days of 30 MPa and shall be composed of one part of cement to 2 parts of sand, unless otherwise approved. All of the sand used in preparation of the mortar shall pass a 4.75 mm sieve.

Before placing the cement mortar bearing pads, the Contractor shall prepare a trial mix of his proposed cement mortar mixture. The equipment used to make the trial mix shall be the equipment to be used during the Contract.

Three standard 95 mm test cubes shall be cast for compression strength testing and cured for 7 days to the satisfaction of the Engineer. The cubes will be air cured on site in a sheltered location.

The three cubes shall be tested for compressive strength at 7 days and each cube shall have a compressive strength of at least 30 MPa. Construction of the bearing pads shall not be started until the strength of the proposed mix has been approved.

The provision of all necessary equipment and carrying out of the sampling of the mortar, the casting, on-site curing and testing of specimens shall be done by the Contractor at his cost.

5.11.4.2 Bearings

The contractor shall supply, fix in position and maintain the bearings strictly in accordance with the drawings and designs of the contract. Care shall be taken in packing, Transportation, storage and handling to avoid any mechanical damage, contamination with oil, grease and dirt, undue exposure to sunlight and installation of multiple bearings one behind the other on a single line of support shall be of identical dimensions.

Bearings shall be placed between true horizontal surfaces (Maximum tolerance 0.2% perpendicular to load) and a true plan position of their centre lines marked on receiving surfaces (maximum tolerances $\pm$ 3mm). The level of the top surface of the elastomeric bearing when installed shall not vary from that shown on the Drawings by more than 3 mm.

Concrete surfaces shall be free from local irregularities (maximum tolerance $\pm$ 1mm in height)

If the Cement mortar bearing pads do not meet these tolerances may be repaired by either grinding the surfaces which will be in contact with the bearings to achieve the desired tolerances or by roughening these surfaces and casting a layer of an approved mortar over the complete surface to a minimum of 3 mm and grinding as necessary. If the above tolerances are not achieved, the Engineer may direct that the bearing pad be removed and replaced by a new pad with the specified tolerances.

For cast in place concrete construction of superstructure, where bearings are installed prior to its concreting the forms around the bearings shall be soft enough for easy removal. Any mortar contamination of the bearings during concreting shall be completely removed before setting.

The contractor shall ensure the presence of an authorized expert of the manufacturer during commencement of the construction activities.

5.11.4.3 Maintenance

After installation routine maintenance, inspection of all bearings shall be made till the expiry of the maintenance period to check for any surface cracking or signs of damage. Damaged bearings shall be replaced immediately. To avoid difference, all adjacent bearings on the same line of support shall also be checked and removed if necessary.

5.11.5 Measurement

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Measurement for payment of furnishing and installing elastomeric bearing shall be made of the number of bearings furnished and installed as shown on the Drawings or directed by the Engineer.

5.11.6 Payment

The unit rate for elastomeric bearing shall include all costs of materials, labor, tools and plants, fabrication, testing, installation and maintenance as per drawing etc all complete.

Pay items shall be

05/11/01(a)	Supply and Installation of Elastomeric bearings	Number
05/11/01(b)	Supply and Installation of Elastomeric bearings	Number
05/11/01(c)	Supply and Installation of Elastomeric bearings	Number
05/11/01(d)	Supply and Installation of Elastomeric bearings	Number

Different Size of Elastomeric bearing as below:

- a) 300 mm × 400 mm × 72 mm
- b) 400 mm × 500 mm × 72 mm
- c) 450 mm × 500 mm × 72 mm
- d) 500 mm × 500 mm × 72 mm

Size may differ based on designer requirement.

Size of different type of bearing will be as per approved drawing.

5.12 BRIDGE BEARINGS (POT BEARING)

5.12.1 Description

The work specified in this Sub-Section includes the supply, manufacture and installation of **pot type** bearings.

5.12.1.1 Design and Applicable Codes

The bearings shall be designed, manufactured and installed in accordance with this specifications and the applicable requirements of the following standard Codes and Specifications:-

Standard specification for Highway Bridges adopted by AASHTO Part I&II Or equivalent

5.12.1.2 Manufacturers

The bearing manufacturer proposed as supplier for the bearings shall have not less than 5 years successful experience in manufacturing similar type and capacity bearings and shall be subjected to the approval by the Engineer.

5.12.1.3 Substituted Bearings

The contractor may submit alternative pot bearings based on pot bearings of similar design to that shown for consideration and approval by the Engineer provided they comply with the following:

- e) Equal or better load carrying and movement capacity;
- f) Fabricated by an approved manufacturer;
- g) All control dimensions are maintained; no change in overall height; bearing must fit within limits of detailed masonry plate;
- h) Use unfilled **Polytetrafluoroethylene (PTFE)**;
- i) Use elastomeric material as a confined medium within the pot.
- j) Equal or better than the bearings shown on the drawings in all structural respects.

5.12.2 Materials

5.12.2.1 Metals

(a) **Stainless steel:** Stainless steel sliding surface shall either be stainless clad steel plate or solid stainless steel meeting the following requirements; -

Stainless steel-clad plate shall conform to the requirements of BS 1449: Part 2. The grade of material for sliding surfaces shall be 316 S16. The backing steel of base metal shall be of Grade 43A to BS 4360. The stainless steel and based metal shall be mill rolled under heat and pressure until they are integrally bonded over their entire interface. Solid stainless steel plate shall conform to the requirements of Bs 1449: Part1.

(b) **Structural Steel:** Structural steel components of the bearing shall comply with requirements of B5 4360. For pot bearings, the bases pot shall be machined from a solid steel plate. All ferrous metal (other than stainless steel) shall be fabricated from the

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grade steel specified above with the additional requirements that the steel shall contain 0.35 to 0.5% copper to enhance its weathering characteristics.

(c) Anchor bolts, Hex Nuts And Washers: Anchor Bolts, Hex Nuts and Washers shall be fabricated from the steel Grade 43 and complying with the requirements of BS 4360 and be sized and threaded in conformance to the requirements of BS 3692 for Anchor Bolts and Hex Nuts and BS 4320 for washers.

(c) Anchor Bolts, Nuts and Washers: Anchor Bolts, Nuts and Washers shall be galvanized and complying with the requirements of BS 729.

(d) Countersunk Screws: Countersunk Screws shall be carbon steel (equivalent to alloy 43, BS 4360) cylindrical head cap screws, meeting the applicable requirements of BS 4933.

(e) End Welded Shear Studs: End Welded shear studs shall be fabricated to the requirements of BS 4360.

5.12.2.2 Poly tetra fluoro ethylene (PTFE)

PTFE resin shall be 100 per cent virgin material meeting the requirements of BS 3784: Grade A.

The composition of filled PTFE shall be such that its coefficient of friction is not more than twice the coefficient of friction of pure PTFE when measured under the same conditions.

a) Filler material

When used, filler material shall be milled glass fibers, carbon or other approved inert filler materials.

b) Adhesives

Adhesives for bonding PTFE to Backing Plates shall produce a bond with minimum peel strength of 4N/mm width when tested in accordance with BS 5350: Part C9. They shall be resistant to the action of lubricants, atmospheric and biological agents and temperature to which bearing may be subject;

c) Lubricant

The lubricant used shall retain its properties within the temperature range of -27⁰ to + 47⁰C. It shall not change its consistency or affect the constituent parts of the bridge bearings. The lubricant shall have the following properties:-

Worked penetration range of 240 to 280 determined in accordance with BS 5296

- i. A solidification point < A40⁰C
- ii. A bleeding < 4% when tested in accordance with BS 5297 using 150⁰C for 24 hour.

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5.12.2.3 Elastomer

- a) Elastomer material shall be good quality natural rubber complying with the requirements of MS 3.51 SMR 5 Grade or better shall be used. All ingredients shall be uniformly dispersed.
- b) The physical properties of the vulcanized rubber when tested according to BS 903 shall conform to the requirements the following physical properties of rubber.
- c) Physical properties of Rubber:

The physical properties of the vulcanized rubber when tested according to appropriate standard shall conform to the requirements of Table 2.11 Bearings whose nominal hardness falls within the ranges of 46-55, and 66-75 are classified as types A, B and C respectively and the properties of the vulcanizates shall conform to the requirements of the respective types. However in all cases the hardness of a single size and design of bearings shall be within a maximum range of ± 5 IRHD. For the purpose of verifying that the bearings conform to the requirements of this clause, all test specimens of ozone resistance shall be taken from an outside surface of a bearing and all other test specimens shall be taken from and outside and middle third of a bearing.

Table 5.12.2 Physical Properties of Elastomer

NO		Type A	Type B	Type C	Methods of Tests
1	Nominal Hardness (IRHD)	46 to 55	56 to 65	66 to 75	ISO 48
2	Tensile strength (N/sq.mm) min	21	17	14	ISO37
3	Elongation at Break (%), min	550	450	300	ISO37
4	Compression set after 24 hours at 70 ⁰ c and 25 Compression (%) Max.	30	30	30	ISO 815
5	Ozone resistance test after 96 hours at 25 pphm ozone, 40 ⁰ C 20% strain	No visible cracks	No visible cracks	No visible cracks	ISO 1431 Part 1

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NO		Type A	Type B	Type C	Methods of Tests
6	Accelerated ageing for 168 hours at 70 ⁰ C				ISO188 (air oven)
	6.1) Change in tensile strength (%)	±15	±15	±15	ISO37
	6.2) Change in elongation at break, (%)	A20	A20	A20	ISO48

5.12.2.4 Coal Tar Epoxy

Coal Tar Epoxy shall comply with the requirements of BS5493 Ref Kf 3B.

5.12.2.5 Preformed Fabric Pads

Preformed Fabric Pads shall be compressed of multiple layers of 227 gram cotton duck impregnated and bound with high quality natural rubber or of equivalent and equally suitable materials compressed into resilient pads of uniform thickness the number of splices shall be subs as to produce the specified thickness after compression and vulcanizing. The finished pads shall withstand compression loads perpendicular to the plane of the laminations of not less than 69KN sq.mm without detrimental reduction in thickness of extrusion.

5.12.2.6 Sealing Rings

Sealing rings for containing the confined medium in pot bearings shall meet the following requirements:

- a) Non-corrosive Materials.
- b) Withstands or transmit all imposed loads.
- c) Allow free movement of the piston.
- d) Contains the confined medium within the pot under the maximum static dynamic loading;
- e) Prevents contamination of the confined medium with foreign matter.
- f) Designed to be flushed with the outside surface of the Elastomer to ensure proper sealing.

5.12.2.7 Grouts

Non shrink grouts for setting anchor bolts shall be of an approved quality and tested in accordance with the requirements of BS 1881, BS 4550, BS 4551 and BS 5075: Part 2.

5.12.3 Design Requirements

Design parameters shall comply with the following requirements:-

5.12.3.1 Elastomeric Disc

The maximum design compressive stress shall be 40 N/sq.mm.

5.12.3.2 Sliding Surfaces

Sliding surface shall accommodate translation by sliding of a hard mating surface of stainless steel across a PTFE surface.

a) Stainless steel

Stainless steel sliding surface shall be accurate, flat surface with Brinnell hardness of 125 minimum it shall comply with the following requirements

- (i) Stainless steel sliding surface shall completely cover the PTFE surface in all operating positions of the bearing.

Stainless steel sliding surface shall be positioned so that the sliding movement causes the dirt and dust accumulation to fall from the surface of the stainless steel without contaminating the PTFE.

b) PTFE Sliding Surface

Holes in PTFE sliding surface shall not be permitted.

c) Coefficient of Friction

Unless otherwise specified the minimum coefficient of friction used in the design shall be as Table 5.12.

Table 5.12-1 Coefficient of Friction for Sliding

Bearing stress (N/sq.mm)	Coefficient of Friction
5	0.08
10	0.06

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20	0.04
30 and over	0.03

5.12.3.3 Rotation

The rotation of pot bearings about a horizontal axis shall not exceed 0.15.

5.12.3.4 Movement

The pot bearings shall accommodate the expansion and contraction movements, as shown on the Drawings.

5.12.3.5 Welding

Welding to steel plate has a bonded PTFE surface may be permitted provided welding procedures are established which restrict the maximum temperature reached by the bond area to less than 1500 (as determined by temperature indication wax pencils or other suitable means approved by the Engineer)

5.12.3.6 Submission of shop drawings

The Contractor shall, before the fabrication of any bearings, submit shop drawings to the Engineer for approval the shop drawings shall include

- a) Plan and elevation of the bearing;
- b) Complete details and sections showing all materials incorporated with the bearing;
- c) All B5, ASTM or other material designations;
- d) Vertical and horizontal load capacity;
- e) Rotation and translation capacity;
- f) Compression stress on all sliding surfaces, as well as on the surfaces of the confines medium, at maximum and minimum design loads;
- g) Complete design calculations to demonstrate compliance with the specification;
- h) Details of corrosion properties to metal components;
- i) Details of fixing to both the superstructure and the substructure;
- j) Method of installation;

All other information required by the Engineer to facilitate his consideration of the contractor's proposal.

The Contractor's submission shall be made at least one month prior to the date by which approval of his proposals is required. The contractor shall be responsible for ensuring that

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sufficient time is allowed for the submission and approval of his proposals; and for the testing and delivery of the bearings, to avoid delaying the works.

5.12.4 Certifications

The Contractor shall furnish Certified Test Reports, Material Certificates and a Certificates of Compliance for each bearing in accordance with the Engineer's instructions.

5.12.5 Fabrication

5.12.5.1 PTFE

- a) Bonded PTFE: The surface of PTFE to be bonded shall be prepared for bonding in accordance with B5 5350: Part A1. The minimum bond strength between the PTFE and its backing plate, when tested in accordance with BS 5350: Part C9, shall be 4N/mm width
- b) Confined PTFE: shall be recessed into metal backing plate. The shoulders of the recess shall be sharp and secure to restrict the flow of PTFE. The thickness of the PTFE and its protrusion from the recess shall be related to its maximum plan dimension in accordance with Table 5.12.1

Table 5.12.5.1: Thickness and Protrusion of PTPE

Maximum dimension of PTFE (diameter or diagonal) (mm)	Minimum Thickness (mm)	Maximum projection above recess (mm)
<600	4.5	2
>600, <1200	5	2.5
>1200, <1500	6	3

5.12.5.2. Bolts and Bolt Holes

Bolt holes shall be drilled or reamed. Where specified by the Engineer, bolts or screw shall be of a vibration resistant type. Taper washers of the correct angle of taper shall be provided under all heads and nuts bearing on beveled surfaces.

5.12.5.3 Welding

- a) General

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Welding procedure shall be as such as to minimize distortion of the bearing components and to avoid damage to finished work or bonded materials

b) Aluminums

Metal-arc welding of aluminum shall be in accordance with the recommendation of BS 3019: Part 1

c) Stainless Steel

Welding of stainless steel sheet to a mild steel backing plate shall be by an inert gas shielded metal-arc tungsten inert gas metal-arc process. Electrodes used with that former method shall be austenitic steel electrodes complying with BS 2926.

5.12.5.4 Protective Measures

Permanently exposed surface shall be protected against corrosion as specified approved by the Engineer.

(a) Dissimilar Materials:

Care shall be taken to prevent electrolytic action between dissimilar metals in contact by the use of suitable insulation and prevention of moisture penetration

(b) Damaged Areas:

Any damaged area of protective treatment shall be made good to the satisfaction of the Engineer or the damaged parts replaced.

5.12.6 Testing

5.12.6.1 Testing facilities for fabrication

The manufacturer shall have his plant for all the test facilities required for the process and acceptance control tests. The test facilities and their operation shall be open to inspection by the Engineer on demand.

Acceptance testing shall be commenced with the prior submittal of testing program by the manufacturer to the Engineer and after obtaining his approval. The Contractor shall inform the Engineer at least one month in advance of the date and place of manufacture and test facilities of the bearing. The Contractor shall make necessary arrangement for the Engineer to inspect the manufacturing process of tests. If the place of manufacture or testing is located overseas, the Contractor shall allow the cost for all expenses incurred by two officers nominated by the Employer for the inspection and testing of bearings. The Contractor shall provide the Engineer with all facilities at the places of manufacture and necessary for such inspection.

5.12.6.2 Sample testing: Procedures and Compliance

(a) Load Testing

Both vertical and horizontal loads shall be applied to the bearing in the most adverse combinations as specified on the Drawing or in the Schedule of Bearings. Load transfer due to tilting of bearing shall be taken into account. Before recorded measurements, the bearing shall be embedded in by applying a load equal to the serviceability limit state and then releasing it. The test loads shall then be applied in increments and load deflection measurements shall be recorded for each increment. The rate of loading shall be slow enough to avoid any adverse shock effects and the maximum load shall be maintained until any obvious short-term creep has ceased.

The load shall then be removed in decrements and load deflection measurements made each decrement. After complete unloading, the amount of set shall be checked and if significant, the loading and unloading cycle shall be repeated. If the set is shown to be progressive, then the bearing is deemed not to comply with this Specification.

For compliance, tested bearing shall show no sign of visible damage or permanent deformation of any part due to loading cycles subsequent to the initial bedding in cycle.

(b) Friction

Friction testing of sliding surfaces shall be carried out as follows:-

A vertical load equal to the permanent load specified on the drawing or listed the schedule of Bearings shall be applied to a pair of sliding surface mounted back to back between the plates of a compression testing rig. A horizontal force shall be applied to the pair of sliding plates sufficient to cause movement of not less than 25mm between the stainless steel and PTFE sliding surface. The maximum force required to cause this movement shall be recorded. The load shall then be removed from the rig and inspected.

The coefficient of friction shall be calculated as (maximum horizontal force) /22x vertical load for each test position and shall in no case exceed Table2.11-2

After testing the stainless steel shall be checked for flatness, which must be within the specified limits. The bond to the backing plate shall be unaffected. The PTFE shall be free from mechanical damage

The tests shall be carried out at room temperature. The PTFE surface shall be lubricated with the lubricant to be used in service. For compliance, tested bearing shall show no apparent surface flaws.

5.12.7 Products Delivery Storage and Handling

5.12.7.1 Assembly and Marking

Each pot bearing shall be assembled at the plant, marked for identification and delivered to the construction site as a complete unit. Each bearing shall be marked to indicate the normal position of the bearing.

5.12.7.2 Care and Protection

During handling, transport, storage and installation, bearings shall be kept clean and protected from mechanical damage, heat, contaminates and other deleterious effects.

5.12.8 Installation

5.12.8.1 General

Bearings which have been pre-assembled shall not be dismantled except with the prior approval of the Engineer if for any reason the bearing has been dismantled, it shall be done under expert supervision and the manufacturer's assistance shall be sought. All bearings whether require providing horizontal restraint or not, shall be fixed to the superstructure with the mechanical fixings or similar. Reliance on the friction between the bearing and the superstructure or substructure to resist part of the horizontal may be permitted provided faces of safety of not less than 1 1½ is applied to the proven coefficient of friction. The worst combination of vertical load and horizontal load shall be considered.

The Contractor shall carefully check the level of any surface, plinth or bed upon which a bearing will rest, and he shall make due allowance for any difference in the depth the bearing to be installed from that assumed on the Drawing. If necessary, he shall adjust the levels of the substructure to ensure that the level of the superstructure will be at the required level on completion.

Unless specified all bearings shall be installed with bottom plate horizontal. For case where tapered top plate is required to take up the longitudinal elevation, welding of bolting to the top of the bearing is not allowed. The tapered top plate must be machined on the bearing itself.

Any temporary lock devices for bearings shall be removed before a post-tensioned case in place superstructure is stressed. For other types of superstructures, the Engineer shall agree the time for removal of any locking devices shall be agreed by the Engineer.

Care shall be taken to avoid displacing bearings during formwork erection, steel fixing and concreting.

The contractor shall ensure the presence of an authorized expert of the manufacturer during commencement of the construction activities.

5.12.8.2 Tolerances

- (a) Bearings shall be located so that their centerlines are within $\pm 3\text{mm}$ of their correct position. The level of bearings shall be within tolerance of ± 0.0001 times the adjacent span or lesser of the adjacent spans but shall not exceed $\pm 5\text{mm}$. Bearings shall be set to their correct inclination within a tolerance of 1 in 200mm in any direction.
- (b) Departure from the plane between twins or multiple bearings shall be within tolerance specified on the drawing.
- (c) Bearing shall be installed so that the directions of their horizontal axis are within tolerance of ± 0.005 radian from their correct alignment.

5.12.9 Shock Transmission Units

5.12.9.1 General

Steel components of shock transmission unit with transverse restraint bearings shall comply with the general requirements except as otherwise stated herein. Other components shall comply with Clauses 2.11. Protection of steelwork against corrosion shall be as specified in SIS 0559000, BS 729, BS 6044, BS 2992, BS 3900, BS 2569 Part1, BS 4921, ISO 8503/Part-2, SSPC Paint, SSPC SP-2, SSPC SP-3 Seismic shock transmission devices shall comply with Clause 3.4.

Details of shock transmission unit shall be as shown on the working Drawings.

The design of the restraints shall make provision facilitate inspection of the device if construction incorporates the robust steel pintle restraint shown on the Consultant's reference Designs then replacement is not anticipated during the designs life of the structure. If, in the opinion of the Engineer, an accepted alternative device may require replacement during the design life of the bridge, then design shall facilitate replacement.

5.12.9.2 Model Testing of Yielding shock Transmission Unit

Scale model rests shall be carried out on shock transmission unit designed to yield under seismic loading.

The Contractor shall submit to the Engineer for approval full details of his proposals for such testing including where the tests are to be carried out and curricula vitae for the key personnel involved.

The Engineer shall be given access to inspect testing at all times and shall have the authority to instruct further amended tests at his discretion.

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Factual reports including all results shall be submitted to the Engineer within one week of the completion of each test. An interpretative report shall be submitted to the Engineer for his approval within one week of the completion of testing.

The models shall not be smaller than one fifth of the size of the actual restraint.

A minimum of six clearly identified test specimens shall be prepared. A minimum of three specimens shall be subjected to the nominal test sequence; a minimum of two specimens shall be subjected to an arbitrary 30% excess deformation and one further specimen tested to a deformation history chosen in the light of the other test results.

Allowance shall be made for a minimum of six further specimens and having different details to assist in design optimization.

The models shall accurately represent the transmission and its fixing arrangements.

Materials tests shall be carried out to relate the material strength and ductility to the materials in the actual transmission.

The nominal test sequence shall accurately represent the deformation history expected for actual transmission. This shall cover both magnitude and rate of deformation

The maximum force developed in each direction of deformation shall be recorded for every cycle, and the force deformation relationship recorded for the first three cycles and thereafter every fifth cycle. The physical appearance of the specimen after the test shall be carefully recorded.

5.12.10 Other types of bearings

5.12.10.1 Steel-laminated Elastomeric/Neoprene bearings

Supplying, fitting and fixing steel-laminated Elastomeric/Neoprene bearings (preferably from Mageba, VSL, Tensa, Watson or equivalent) in exact positions as per drawing, specifications and direction of the E-I-C including cost of all materials, labor, carrying etc. The set shall be of 100% virgin Chloroprene Rubber (CR), grades of raw elastomer of proven use in elastomeric bearings, with low crystallization rates and adequate shelf life viz. Neoprene WRT, Neoprene W, Bayprene 110, Bayprene 210, Skyprene B-5, Skyprene B-30, Denka S-40V and Denka M-40, shall be used. No reclaimed rubber or Vulcanized wastes or natural rubber shall be used. Use of synthetic rubber-like materials such as Ethyl Propylene Dimonomer (EPDM), Isobutane Isoprene Copolymer (IIR) and Chloro-Isoprene Copolymer (CIIR) shall not be permitted. Laboratory test to be performed from certified laboratory for compliance according to special provisions for different types of bearings determined in accordance with relevant standards.

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5.12.10.2 Spherical Bearing

Supplying, fitting & fixing in position true to line and level cast steel spherical/cylindrical type bearing with stainless steel plate with PTFE sliding surface as per AASHTO specifications [ASTM D5977-23: Standard Specification for High Load Rotational Spherical Bearings for Bridges and Structures], complete with all accessories as per drawing & direction of E-I-C and including cost of all material installation. One set must be taken as extra for laboratory test which to be performed from BUET.

5.12.11 Measurement

The method of measurement for payment shall be in number for each Bearing and for each shock Transmission Unit with Transverse Restraints.

5.12.12 Payment

The Contract unit rate for the items shown in the BOQ shall include cost of all materials, equipment and other incidental charges for supply, installation and fixing in all respects per these specifications and as shown in the drawing.

Pay items shall be

5/12/01	Supply and Installation of Pot bearings	Number
05/12/01(a)	Supply and Installation of Pot bearings (500 mm × 500 mm × 72 mm)	Number
05/12/01(b)	Supply and Installation of Pot bearings (500 mm × 450 mm × 72 mm)	Number
05/12/01(c)	Supply and Installation of Pot bearings (400 mm × 300 mm × 72 mm)	Number
5/12/02	Supply and Installation of Shock Transmission units	
05/12/02(a)	Supply and Installation of Shock Transmission units (up to 50 MT of horizontal load)	Number

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05/12/02(b)	Supply and Installation of Shock Transmission units (Above 50 MT of horizontal load)	Number
5/12/03	Supply and Installation of Steel-laminated Elastomeric/Neoprene bearings	Number
5/12/04	Supply and Installation of Spherical bearings	Number

Size of different type of bearing will be as per approved drawing.

5.13 BEARING REPLACEMENT

5.13.1 Description

This work consists of furnishing all labor, tools and equipment for jacking and supporting the existing beams/slab while removing the bearing assembly. The Contractor is responsible for the complete design of the bridge lifting procedures and the materials used. The Contractor shall furnish and place all bracing, shoring, blocking, cribbing, temporary structural steel, timber, shims, wedges, hydraulic jacks, and any other materials and equipment necessary for safe and proper execution of the work. The Contractor shall remove and dispose of the bearings according to the Standard Specifications.

The bridge deck, substructure and bearings shall be designed and detailed to permit future bearing replacement of each and every bearing and jacking points shall be clearly shown on the drawings.

- No reduction in traffic loading shall be considered during bearing replacement.
- A maximum jacking movement of 10mm shall be assumed for bearing replacement.

5.13.2 Construction

The Contractor shall submit details and calculations of his/her proposed jacking systems and temporary support procedures for approval by the Engineer before commencing work. If unforeseen field conditions preclude the execution of the approved jacking plan, the Engineer may require the Contractor to provide additional supports or measures. All changes to the jacking plan shall be approved by the Structural Engineer that sealed the jacking plan. Neither added precautions nor the failure of the Engineer to order additional protection will in any way relieve the Contractor of sole responsibility for the safety of lives, equipment and structure.

(a) Jack and Remove Existing Bearings with bridge deck in place. Jacking and cribbing under and against the existing diaphragms, if applicable, will not be allowed. The Contractor's jacking plans and procedures shall be designed and sealed by a Licensed Structural Engineer. In all cases, traffic shall be removed from the portion of the structure to be jacked prior to and during the entire time the load is being supported by the hydraulic pressure of the jack(s). The minimum jack capacity per beam shall be as noted in the plans. Whenever possible, traffic shall be kept off that portion of the structure during the entire bearing replacement operation. The shoring or cribbing supporting the beam(s) during bearing replacement shall be designed to support the dead load plus one half of the live load and impact shown in the plans. If traffic cannot be kept off that portion of the structure during the bearing replacement, then the shoring or cribbing supporting the beam(s) shall be designed to support the dead load and full live load and impact shown in the plans. No jacking shall be allowed during the period of placement and cure time required for any concrete placed in the span(s) contributing loads to the bearings to be jacked and removed. Jacking shall be limited to 1/8 in. (4 mm) maximum when jacking one bearing at a time. Simultaneous jacking of all beams at one support may be performed provided the maximum lift is 1/4 in. (7 mm) and the maximum differential displacement between adjacent beams is 1/8 in. (4 mm). Suitable gauges for the measurement of superstructure movement shall be furnished and installed by the Contractor.

(b) Jack and Remove Existing Bearings when entire bridge deck is removed. Jacking and bearing removal shall be done after the removal of the existing bridge deck is complete. The Contractor's plans and procedures for the proposed jacking and cribbing system shall be designed and sealed by a Licensed Structural Engineer unless jacking can be accomplished directly from the bearing seat under the beams or girders.

Jacking shall be limited to 1/4 in. (7 mm) maximum when jacking one beam at a time. Simultaneous jacking of all beams at one support may be performed provided the maximum lift is 3/4 in. (19 mm) and the maximum differential displacement between adjacent beams is 1/4 in. (7 mm). When staged construction is utilized, simultaneous jacking of all beams shall be limited to 1/4 in. (7 mm) unless the diaphragms at the stage line are disconnected, in which case the maximum lift is 3/4 in. (19 mm). Suitable gauges for the measurement of superstructure movement shall be furnished and installed by the Contractor.

The Contractor shall be responsible for restoring to their original condition, prior to jacking, the drainage ditches, pavement, or slope wall disturbed by the cribbing footings.

The contractor shall ensure the presence of an authorized expert of the manufacturer during commencement of the construction activities.

5.13.3 Payment

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This work will be paid for at the contract unit price each for jack and remove existing bearings.

XXXXXXXX	Jack and Remove Existing Bearing	Nos

5.14 BRIDGE SUPER-STRUCTURE (PRECAST PRESTRESSED CONCRETE GIRDERS)

5.14.1 Description

This specification relates to transportation, loading, unloading and erection of precast prestressed concrete girders. The specification outlines work associated with transportation, material proposal, erection, tolerance criteria, temporary works as well as measurement of payment for the girders.

A precast prestressed concrete girder shall be used for bridge in straight alignment and for curved bridges where the radius of the horizontal curve is very large. The span of the girder shall be 20m to 55m. For a span of more than 50m the girder shall be cast in place over the pier or abutment.

5.14.2 Materials

5.14.2.1 Girder

Precast Prestressed Concrete Girders will be supplied by the Contractor at the precast Fabricator's yard. The precast fabricator will load the girders onto the contractor's hauling equipment. Pick-up of girders shall be during the Fabricator's normal working hours unless other or otherwise mutually satisfactory arrangements are made between the Contractor and the Fabricator. The Contractor shall be responsible for the security and integrity of the girders during transportation to site, and during unloading, storage and erection on site. Girders damaged during any of these operations shall be replaced or repaired to the satisfaction of the Engineer before final approval is granted. The decision to repair or replace the damaged girders will be entirely at the discretion of RHD.

5.14.2.2 Bearings

The Contractor shall supply bearings in accordance with the requirements of the specification and details on the Drawings and as per approved material proposal submitted by the contractor.

5.14.2.3 Non-Shrink Grout

The contractor shall submit a material proposal for non-shrink grout for the grout pads which must be approved by the Engineer.

5.14.3 Construction

5.14.3.1 General

Transportation, unloading and erection of the precast prestressed concrete girders shall be under the direction of a Professional Engineer, registered and licensed to practice. The Professional Engineer shall be experienced in bridge girder transportation and erection and be present for all stages of girder loading, unloading and erection. The precast prestressed concrete girders shall be picked up only by the lifting devices installed by the Fabricator.

During storage and transportation, the girders shall be maintained in an upright position and shall be supported within 500 mm of the bearing areas. The machined surfaces of steel bearing components cast into the girders shall be protected from damage at all times.

5.14.3.2 Handling and Transportation of Girders

The Fabricator shall load, and the Contractor shall transport all of the girders in accordance with the following unless and other-wise any alternate method statements approved by the Engineer in charge:

- i) The Contractor shall be responsible for the design, supply, installation and removal of temporary bracing for girders as may be required during the Contractor's handling and transportation of the girders. Should the Contractor choose to transport the girders to a temporary storage location, he shall be responsible for additional loading, transporting, unloading and storage procedures. The submission of design calculations and Shop Drawings for the temporary bracing to the Engineer shall in no way relieve the Contractor of the full responsibility for the success or failure of the design.
- ii) The Contractor shall submit his proposed route for transporting the girders including traffic control procedures as part of the proposed Transportation Plan. In all traffic control situations, the flagman must be trained and properly attired in flagman's vest and approved headgear with approved flagman's stop/slow paddle or fluorescent red flag. The proper advance signing must also be in place.

When transporting bridge girders using equipment other than a flatbed trailer, the Contractor shall be responsible for ensuring the following:

- Travel speed not to exceed 80 kph.
Travel only in daylight between sunrise and sunset; and

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Travel will not be allowed on weekends or statutory holidays unless authorized by the Engineer.

When transporting bridge girders, the Contractor shall be responsible for ensuring that all of the required permits have been acquired and the conditions of all permits are met.

- Extreme care shall be exercised during the handling and transportation of the precast girders to avoid twisting, cracking or other distortion that may result in damage to the girder. The Contractor shall be responsible for protecting the girders at restraint points on the vehicle. All damaged corners or surfaces of the girders will be regarded as honeycomb and shall be repaired as directed by the Engineer.
- No loose timber blocking will be permitted for use in temporary works for any aspect of girder handling and transportation.

It is the Contractor's responsibility to ascertain the actual weight of the girders. The concrete in the precast prestressed girders may be denser than regular concrete and the girders contain a high percentage of reinforcing steel and stressing strands which also tend to increase the weight of the girders.

5.14.3.3 Temporary Work

Temporary works including work bridges and platforms, barges, erection bracing, wind bracing, and lateral stability bracing required for handling, transportation and erection of precast prestressed concrete girders shall be installed and constructed in accordance with the Contractor's approved design and Shop Drawings.

5.14.3.4 Installation of Bearings

The Contractor shall install bearings in accordance with the requirements of the specification and details on the Drawings and as per approved method statement submitted by the contractor.

5.14.3.5 Erection of Girder

Before erecting the girders, the Contractor shall verify that the lengths of the girders, the layout of the substructure units, the elevations of the bearing seats, and the location of the anchor bolts are as shown on the Drawings. All discrepancies discovered by the Contractor shall be brought immediately to the attention of the Engineer.

It is essential that the girders be erected with utmost attention being given to girder positioning, alignment and elevation. The Contractor shall adjust girder position, bearing location, and bearing elevation in order to achieve as closely as possible the lines and grades shown on the Drawings. The Contractor shall minimize any differential camber (girder to girder), and the sweep of the girders by jacking, loading of girders, winching, or whatever means are necessary, and shall provide the necessary temporary attachments to

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hold the girders in position. The Engineer shall approve all proposed methods of jacking, loading, winching, etc. prior to the work being undertaken.

The maximum dimensional deviation in mm, of erected precast prestressed concrete girders from that as detailed on the Drawings shall not exceed the following:

Sweep (NU Girders) 1 mm/m

Sweep (Other Girders) Deviation from true, $20 \text{ mm} \times \text{length (m)} / 50$

Approved the erected positions of the girders, all lifting hooks shall be cut off 50 mm below the top surface of the girder and all lifting hook pockets shall be filled with an approved high strength non-shrink grout. In cases where a concrete deck is going to be cast over the lifting hook locations, the lifting hooks are to be cut off flush with the top of the girders. All lifting holes shall be filled with an approved high strength non-shrink grout.

Temporary erection bracing, wind bracing and lateral stability bracing shall be designed and installed in order that it will not interfere with the forming and pouring of the diaphragms and deck and shall remain in place until seven (7) days after the pouring of the diaphragms.

The different possible lifting methods of girder are outlined below:

Girder lifting by Crane

Beams should be picked up and supported only at the designated pick-up points, unless the plans state otherwise. These pick-up points are loops extending out of the tops of the beams (one near each end). The pick-up cable should maintain a safe slope. A safe maximum amount would be 1:1.5. If a flatter slope is used, the beam may be damaged. Contractors may use more than one crane if necessary. The plans for the pickup position and lifting method according to girder shape shall be approved by the Engineer in charge.

Girder lifting by Grid launcher

Beam / Grid Launcher is used in the erection of precast beam bridges for span by span method of construction for precast beam girders like U-beam, T-beam, I-beam, etc. This mainly consists of main beam, cantilever beam, under guide beam, front and rear support legs, auxiliary outrigger, hanging beam crane, jib crane and electro-hydraulic system. Designed for precast beam assembly without crane assistance the Beam Launcher is widely used for plain construction, can also meet the requirement for mountain building highway slope, small radius curved bridge, skew bridge and tunnel bridge. There are 2 types of Beam/ Grid Launchers: the single-box type and the double-truss type. Launcher types are used depending on the requirements of the project and with transport trolleys either on rails or with tyres depending on gradient and length of the bridge. The Beam/ Grid Launcher gives a good stability, high efficiency, safety and reliability, easy to adjust variable cross and easy to operate. It has three methods for picking up the precast beam: from rear end of

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the beam launcher on the deck level, from below on ground level, or from the bridge side. The launcher can accomplish the girder carrying with erecting at the same time. It can also erect 4 pieces of girders with another two cranes one day, saving construction cycles. It comprises a main beam, cantilever, under guide beam, front and rear legs, auxiliary outrigger, hanging beam crane, cantilever crane and electro-hydraulic system. The methodology for lifting using Grid Launcher shall be approved by the Engineer in charge.

Girder lifting by Gantry cranes

Gantry cranes can be equipped to lift precast beams, or a single crane with double spreaders to lift precast beams. The lifting weight of two cranes that lift at the same time is generally 450 tons, and the lifting weight of a single crane may be up to 900 tons. The crane is composed of outriggers, crane running and lifting mechanism, which can realize all-round mechanized action. This gantry crane for bridge construction is mainly used to lift and move the precast beam from the beam-making platform to the beam storage platform. After the precast beam is maintained, it will be lifted from the beam storage platform to the beam transport vehicle. The gantry crane can complete the assembly and disassembly of the bridge erector, and it is also used to erect dry bridges with low piers.

The lifting system in gantry cranes adopts a four-point fixed lift beam, which is balanced by the load to ensure the safety of the concrete box girder and the lifting system's structure. Through the vertical and horizontal fine adjustment of the lifting mechanism, the accuracy of box girder erection can be achieved. The methodology for using Gantry Cranes shall be approved by the Engineer in charge.

Girder lifting by Segment lifter

Segment lifter can be best utilized for Balanced cantilever construction where pre-casting is possible and the segment can be transported below the span. This Equipment allows the erection of industrialized segments and faster erection and is therefore addressed to bridges with a great number of spans. Since these are very specialized equipment, the fabrication is mostly done at the centralized fabrication unit and it's being shipped to various sites. A segment lifter is launched through a hydraulic system which gives a safe launching for the equipment. The segment lifter allows faster erection and is therefore addressed to bridges with a great number of spans. It is equipped with two electric hoists for lifting the precast segments and adjusting the cross-fall. Segment lifters are usually designed to install segments in ramps, in tight locations, or in areas that are generally difficult to access. It incorporates two primary hydraulic systems providing both lifting of segments and moving of the frame itself during construction when high lifting speeds are required, tandem lifting units or winch systems are utilized on segment lifter. The methodology for using Segment Lifter shall be approved by the Engineer in charge.

5.13.3.6 Measurement

The delivery of precast prestressed concrete girders will be measured on a unit basis and the number to be paid for will be the total number of girders delivered and accepted by the engineer. The erection of precast prestressed concrete girders will be measured on a unit basis and the number to be paid for will be the total number of girders erected and accepted by the Engineer.

5.13.3.7 Payment

Delivery of precast prestressed concrete girders will be paid for at the Contract Unit Price per girder for “Delivery of Precast Prestressed Concrete Girders”, measured as specified herein, which price will be payment in full for performing all operations herein described and all other items incidental to the work including in this Specification.

Erection of precast prestressed concrete girders will be paid for at the Contract Unit Price per girder for “Erection of Precast Prestressed Concrete Girders”, measured as specified herein, which price will be payment in full for performing all operations herein described and all other items incidental to the work as approved by the Engineer.

Pay Item No.	Description	Unit Measurement
xxxxxxx	Delivery and Erection of Prestressed Concrete Girders	nos

5.15. BRIDGE SUPER-STRUCTURE (PRE-CAST/ CAST IN-SITU VOIDED SLAB)

5.15.1 Description

A voided concrete slab is a system that removes the non-working or excess concrete from the structural slab and replaces it with void formers. Voided slabs can be either in reinforced concrete or in prestressed concrete.

Voids can be either circular or rectangular in shape. Void formers may be manufactured from steel sheets, fibre-reinforced cement, expanded polystyrene, HDPE, etc. They are generally corrugated to attain sufficient rigidity in order to prevent distortion or collapse during concrete. They should also be leak tight.

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Void formers shall be suitably tied down in order to prevent flotation during concreting. Care shall be taken during placement of concrete to ensure that the concrete flows fully into the space beneath the void formers.

A cast-in-place voided slab shall be used as a superstructural system for the via-duct portion of the bridges, especially in a short span curved portion of the alignment. This type of slabs may be used in sharp curved portions where superelevation and transient curves are introduced. The appropriate span length for this type of slab may be in between 10m to 15m.

5.15.2 Construction

The construction shall be carried out according to the contractors' proposed method statement approved by the Engineer. The following criteria shall be followed for tolerance of girder during the construction:

Precast Concrete Superstructure

- a) Variations in thickness of top and top and bottom flange for T-girders and slabs
: ± 5 mm to bottom slab for box girders,
- b) Variations in web thickness : -5 mm to +10 mm
- c) Variations in overall depth or width : ± 5 mm
- d) Variation in length overall and length : shall not exceed ± 10 mm between bearings or ± 0.1 percent of the span length, whichever is less
- e) Permissible surface unevenness in Cast In-Situ Superstructure
: 5 mm deck slab when measured with a 3 m straight edge or template

Cast-In-Situ Superstructure

- a) Variations in thickness of top and bottom slab for box girders, top and bottom flange for T-girders and slabs : -5 mm to +10 mm
- b) Variations in web thickness : -5 mm to +10 mm
- c) Variations in overall depth or width : ± 5 mm
- d) Variation in length overall and length : shall not exceed ± 10 mm between bearings or ± 0.1 percent of the span length, whichever is less
- e) Permissible surface unevenness in : 5 mm deck slab when measured with a 3 m straight edge or template

5.15.3 Measurement

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Structural concrete shall be measured in cubic meters. In reinforced or prestressed concrete, the volume occupied by reinforcement or prestressing cables and sheathing shall not be deducted. The slab shall be measured as running continuously through and the beam as the portion below the slab. Based on the quantity ordered or as shown on the approved drawings.

Steel reinforcement shall be measured in length including hooks, if any, separately for different diameters as actually used in work, excluding overlaps. From the length so measured, the weight of reinforcement shall be calculated in tonnes. Wastage overlaps, couplings, welded joints, spacer bars, chairs, stays, hangers and annealed steel wire or other methods for binding and place, shall not be measured and the cost of these items shall be deemed to be included in the rates for reinforcement based on the quantity ordered or as shown on the drawings. Concrete Superstructure High tensile steel (prestressing) in superstructure shall be measured in cubic meters. The volume occupied by mild steel reinforcement/HYSD bars, high tensile steel, sheathing and anchorages shall not be deducted.

High tensile (prestressing) steel shall be paid for separately. Its length, as actually incorporated in the finished work, shall be measured and weight calculated therefrom in tonnes on a theoretical basis, for payment. Anchorage devices, the additional length of cables for attaching jack, ducts or sheathing, grouting, non-prestressed steel reinforcement fixed to the anchorage devices, making of recesses and filling the same, protection by painting with epoxy and furnishing samples for testing, shall all be deemed to be incidental to and included in the item of high tensile steel and shall not be measured separately, based on the quantity ordered or as shown on the drawings.

5.15.4 Payment

The contract unit rates for concrete, steel reinforcement (untensioned) and high tensile steel (prestressing) shall include all works as given in respective Sections of these Specifications and cover all incidental items for furnishing and providing superstructure as mentioned in this Section and as shown on the drawings.

Pay Item No.	Description	Unit Measurement
xxxxxxx	Concrete of specified grade	cum

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xxxxxxx	Reinforcing steel bar	tonne
xxxxxxx	High tensile prestressing steel	tonne

5.16. BRIDGE SUPER-STRUCTURE (PRE-CAST/CAST IN-SITU SEGMENTAL BRIDGE)

5.16.1 Description

Fabricate, store, transport and erect precast structural concrete superstructure and/or substructure segments on a prepared foundation, to the established lines and grades, in accordance with the design, dimensions and details shown on the drawings and in accordance with this section.

A pre-cast or cast-in-situ segmental bridge shall be constructed where a large span bridge span is required. The applicable length of the main span is 80m to 110m. The length of the end span may vary from 0.6 to 0.75 times the main span length depending on the design requirements. This type of construction method is appropriate where staging is not possible due to substantial velocity of water flow or busy traffic condition under the main span.

5.16.2 Construction

5.16.2.1 General

The contractor shall use methods and procedures providing adequate safety to the general public from construction/erection activities and/or falsework placed over or adjacent to travelled roadways, navigational or recreational waterways or any existing commercial, industrial or another facility.

All work shall be carried out based on approved shop drawings, method statements and material proposals approved by the Engineer.

5.16.2.1 Casting Works

The casting works for specification involve a comprehensive set of procedures and requirements for the fabrication of segments in a casting yard. The contractor shall outline the layout of the casting yard setup and operation of casting cells, use of rain and sunshades, geometry control stations, rebar cage storage and handling, and other related aspects.

Additionally, detail calculations and procedures for lifting, storing, and stacking segments within the casting yard shall be included in the method statement submitted by the contractor. Established procedures for erection mark and segment identification shall be outlined at an early stage. Segment transport plan from casting yard to construction site will need prior approval from competent authority. Adherence to material conformance as per material specification shall be ensured prior to construction

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Detailed guidelines shall be provided for forms, geometry control, preparation for match, casting, embedded items, concrete placement, consolidation, finishing, curing, removal of forms, and testing samples at various stages.

All associated works shall be prior approved by the Engineer in charge.

5.16.2.2 Embedded Elements

Embedded items, as outlined in the specifications, must comply with the requirements for prestressed and post-tensioned construction. For embedded post-tensioning ducts, accuracy in positioning is crucial, and positive methods should be employed to prevent displacement or damage during concrete placement. Adequate securing of ducts to the reinforcement cage is required, with closer supports for small or flexible ducts. Sealing duct ends is mandatory to prevent water and debris entry, and verification of unobstructed ducts is essential before and after concrete pours. Anchorage plates and castings must be fixed, connected, and sealed before concrete placement, ensuring rigidity for correct alignment. Regarding reinforcing steel, adherence to plans, proper alignment with post-tensioning ducts, and meticulous placement within specified tolerances are emphasized, with any necessary replacements subject to Engineer approval.

5.16.2.3 Tolerances

The following tolerances apply to the fabrication of precast components:

Superstructure Box Segments	
Width of Web	±6.35 mm
Depth of bottom slab	±4.7625 mm
Depth of top slab	±4.7625 mm
Overall depth of segment	±4.7625 mm
Overall width of segment	±6.35 mm
Length of segment	±9.525 mm
Diaphragm dimensions	±9.525 mm
(2) Precast Box Pier Segments	

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Height (Individual Element)	±6.35 mm
Width and Breadth (Individual Element)	±6.35 mm
Thickness (wall)	±6.35 mm
(3) All Fabricated Segments	
Ends (deviation from a plane per 6m width or depth)	±6.35 mm inch per 6m not to exceed 12.7 mm
Flat Surface (deviation from a plane at any location)	±2 mm/m not to exceed a total of ±6.35.

5.16.2.4 Erection

Before commencing erection operations, submit proposals for all segment erection operations to the Engineer for approval. This submittal must be in the form of an “Erection Manual” and include but not necessarily be limited to:

A detailed step-by-step sequence for the erection of each segment including all intermediate procedures relating to erection equipment, temporary and permanent post-tensioning and the making of closures between spans and/or cantilevers and another required sequencing.

Positioning, use and sequencing of falsework, jacking and/or releasing of falsework, temporary towers, supports, tie-downs, counterweights, closure devices and the like.

Positioning, use and sequencing of erection equipment such as cranes, beam and winch devices, gantries, trusses and the like, both on and off the structure, including the movement, introduction and/or removal of any supports onto or connections with the structure. Include drawings and calculations for the structural effects of erection equipment on the structure.

Detailed scheduling of all temporary and permanent post-tensioning operations and sequences in accordance with the segment erection and closure operations and other required scheduling.

Stressing forces and elongations for post-tensioning.

Sequencing of filler injection operations.

A method for the field survey control for establishing and checking the erected

geometry (elevations and alignments) with particular attention to the setting of critical segments such as, for example, pier segments for balanced cantilever erection. This information may be included in the Erection Manual or may be submitted later as a supplementary or separate document.

Any other relevant operations as required and applicable to the structure type and construction method.

No erection shall commence without prior approval of the method statement by the Engineer in charge.

5.16.3 Measurement

Precast superstructure segment concrete, including cast-in-place concrete for closure and wet joint pours, will be measured by volume according to the quantities represented by the dimensions of the segments and cast-in-place pours on the approved shop drawings.

All reinforcement in precast superstructures, cast-in-place closures and wet joints will be measured by weight according to the quantities represented by the reinforcement details approved shop drawings.

All permanent post-tensioning in the superstructure will be measured by weight according to the quantities represented by the details in the approved shop drawings.

5.16.4 Payment

Payment for precast superstructure segment concrete will be at the contract bid prices per cubic meter for the various classes of concrete called for such prices and payments will be full compensation for manufacture, storage, transport, assembly, and erection of the segments complete and in place, including filling all concrete blackouts and similar miscellaneous details. These prices and payments will also include the furnishing and the application of epoxy bonding agent and finish coating when specified in the drawings, providing temporary and permanent segment access details, material testing, special erection equipment, temporary post-tensioning, tools, labor and incidental items necessary for completing the work in accordance with the specifications and approved shop drawings.

No additional payment will be made for extra concrete necessitated by approved modifications to the segments or structure needed to accommodate the Contractor's construction methods.

Payment for reinforcement in precast segments, closure pours, wet joints and other cast-in-place concrete joints and details will be at the Contract bid price per tonne for reinforcing steel (superstructure) and for reinforcing steel (substructure).

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No additional payment will be made for extra reinforcement necessitated by approved modifications to the segments or structure for the purposes of the Contractor's construction methods.

Pay Item No.	Description	Unit Measurement
xxxxxxx	Concrete of specified grade	cum
xxxxxxx	Reinforcing steel bar	tonne
xxxxxxx	High tensile prestressing steel	tonne

5.17. COUPLER

5.17.1 Description

This work shall consist of furnishing and placing of coupler or mechanical splice with Specifications and in conformity with the requirements mentioned in AASHTO, BNBC, ISO or any other equivalent standards. The mechanical splice is defined as complete assembly of a coupler or an end-bearing sleeve including any additional intervening material or other components providing a splice of two reinforcing bars. Reinforcement coupler is termed as coupling sleeve or threaded coupler for mechanical splices of reinforcement bars for the purpose of providing transfer of axial tension and/or compression from one bar to the other bar where,

- coupling sleeve is a device fitting over the ends of two reinforcing bars,
- threaded coupler is a threaded device for joining reinforcing bars with matching threads.

5.17.2 Material and requirements

The requirements apply to the coupler even though the check of the properties of the coupler is carried out on a mechanical splice that has been installed in accordance with the manufacturer's written instructions.

The technical requirements for couplers are related to the following properties where i)

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and ii) are mandatory while iii) and iv) are related to categories defined in ISO 15835-1 Sec 5.2

Strength and ductility under static forces:

Strength and ductility of the mechanical splice shall be verified by testing to satisfy the requirements of both ISO 15835-1:2018, Sec 5.3.2 and Sec 5.3.3 or any other equivalent standard. A reference bar from the same heat of steel shall be tested to verify that its measured strength and ductility satisfy the minimum values specified in the product standard of the bar.

It is preferable that the test splice and the reference bar come from the same length of reinforcing bar.

For surveillance testing, if all samples of the mechanical splice tensile strength tests fail outside the length of the mechanical splice and the mode of failure of the bar is ductile (including necking), and the measured tensile strengths comply with the product standard of the bar, no verification of the ductility of the mechanical splice is required. If couplers are used to connect bars of different sizes, the strength and ductility requirements shall be based on the smaller reinforcing bar diameter.

Strength: The tensile strength of the mechanical splice shall be at least $ReH \times (R_m/ReH)_{spec}$.

If R_{mspec} is the value specified in the reinforcing bar standard, the tensile strength of the mechanical splice shall be at least $R_m, spec$.

Ductility: Requirements for the ductility of spliced bars are to ensure that the use of the mechanical splice maintains a minimum ductility in the reinforcement. The ductility of the coupler itself is not subject to testing.

The minimum A_{gt} measured in accordance with ISO 15630-1:2018 on the reinforcing bar outside the length of the mechanical splice shall not be less than $0,7A_{gt}$, where A_{gt} is the specified characteristic value of the reinforcing bar taken from the product standard of the reinforcing bar.

Where A_{gt} is not specified for the reinforcing bars, a minimum value of 3 % shall be attained in the bar outside the mechanical splice before failure of the test piece.

Slip under static forces:

The median value of all test results shall not exceed 0.10 mm. The outlier values shall, however, not exceed the maximum allowable slip by more than 0.05 mm.

NOTE 1: Slip requirement is important for limitation of crack widths in exposed reinforced concrete structures.

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NOTE 2: The purpose of using the median value for the evaluation of results is to filter-out questionably high and low values, as this test is performed by a multitude of measurement devices and fixtures that are not yet covered by a standard. For couplers longer than 100 mm, a slip greater than 0,10 mm may be accepted.

NOTE 3: The reason for this provision is that the longer the coupler, the larger the volume of concrete through which the coupler slip will dissipate.

Properties under high cycle fatigue loading in the elastic range:

The largest diameter of mechanical splices of category F shall be tested in fatigue. The manufacturer may sub-divide the product range in several groups of diameters and test the largest diameter of each group in order to characterize the performance.

NOTE 1: When tested in air, the worst fatigue results normally occur on the largest diameter.

NOTE 2: The fatigue performance of a mechanically spliced bar will usually be lower than that of the un-spliced bar.

Fatigue performance

Mechanical splices of category F shall sustain a fatigue loading of at least 2 million cycles with a stress range, $2\sigma_a$, of 60 MPa without failure. The maximum stress, σ_{max} , in the test shall be $0,6ReH, spec$.

The tests shall comply with the following acceptance criteria.

- If all test pieces do not fail before reaching two million cycles, the test is passed.
- If one test piece fails the test, three additional test pieces from the same batch shall be tested. If all three additional test pieces pass, the test is passed.
- If two or more test pieces fail the fatigue test, the test is failed.

Properties under low cycle reverse loading in the elastic-plastic range:

Mechanical splices of category S shall be tested in reverse elastic-plastic loading. The performance requirements for mechanical splices subject to tension and compression tests simulating an earthquake are the average residual elongation after the first 20 cycles u_{20} shall not exceed by more than 0,3 mm the equivalent residual elongation of an un-spliced reference length from the same bar, measured on the same gauge length,

- the mechanical splice shall survive the strain cycles in stages 2 and 3 of the test, and
- the ultimate tensile strength shall exceed the value specified in the specification clauses: $R_m, spec$ or $ReH \times (R_m/ReH)_{spec}$

The requirement on u_{20} may be disregarded if allowed in national provisions and agreed between the purchaser and the supplier.

Testing of these properties shall be carried out in accordance with ISO 15835-2 or equivalent standards.

5.17.3 Construction

i) Cutting: Only saw cutting of bars are allowed. Shear cutting, gas cutting, or any other cutting method is strictly prohibited.

- Holding width of the machine's vice shall be adjusted to fit the bar size.
- A trial cutting shall be performed to ensure smooth operation.
- Saw blades must be inspected regularly and be in good condition. Worn or damaged blades shall be re-sharpened or replaced.

ii) Forging: The contractor shall select the right die grips/ die pockets according to the rebar diameter. Both sides of the Die grips/pockets from the same batch. The roller height needs to be positioned in accordance with the operation manual. The correct height is reached when the rebar is almost touching the roller when the clamp is closed. Pressure setting and forging length must be adjusted correctly as per the machine's operation manual to ensure the diameter after forging is within the specifications. A trial forging shall be performed to ensure that the correct diameter after forging as per "Machine setting table" is achieved and operation runs smoothly.

iii) Threading: The cutting head and carriage clamp must be aligned. The threading speed shall be adjusted in accordance with the recommendations given in the operation manual. The shift guides shall not be worn out and in good condition. Chaser condition needs to be inspected at regular intervals and re-sharpened when damaged or worn. The thread diameter needs to be set in accordance with the bar diameter used. Use the setting gauge or a thread sample corresponding to the thread core diameter in accordance with the operation manual. The threading length needs to be set in accordance with the given tolerances. The setup shall be checked on a test piece.

5.17.4 Measurement

Since the type and size of coupler may vary based on requirement purpose hence, measurement for the couplers to be quantified in nos.

5.17.5 Payment

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This work shall be paid for at the Contract unit price per piece of coupler for the particular type and size.

Pay Item No.	Description	Unit Measurement
xxxxxxx	Coupler of specified type and size	Nos

5.18. WELDED WEIR REINFORCEMENT (WWR)

5.18.1 Description

This work shall consist of furnishing and placing of welded wire reinforcement (WWR) or welded fabric with Specifications and in conformity with the requirements mentioned in BNBC, ISO or equivalent standard.

5.18.2 Material and requirements

The BDS ISO 6935-3:1992 specifies technical requirements for factory made sheets or rolls of welded fabric, manufactured from steel wires or bars with diameters from 4 mm to 16 mm and designed for the reinforcement of concrete structures and the ordinary reinforcement of prestressed concrete structures. For the purpose of BDS ISO 6935-3:1992, the term “wire” also includes bars. The fabric shall be made of either

- Cold-reduced wires with nominal diameters in the range from 4 mm to 16 mm (recommended: 4.5 mm, 5 mm, 6 mm, 7 mm, 8 mm, 9 mm, 10 mm and 12 mm) and with mass and geometry complying with ISO 10544 or equivalent
- Plain bars with nominal diameters of 6 mm, 8 mm, 10 mm, 12 mm or 16 mm (recommended: 6 mm, 8 mm, 10 mm and 12 mm) and with mass complying with BDS ISO 6935-1:2009 or equivalent.
- Ribbed bars with nominal diameters of 6 mm, 8 mm, 10 mm, 12 mm or 16 mm (recommended: 6 mm, 8 mm, 10 mm and 12 mm) and with mass and geometry complying with BDS ISO 6935-2:2016 or equivalent.

All fabric shall be machine made, and the joints at the intersections of the longitudinal and transverse wires shall be made by electrical resistance welding to provide shear resistant connections.

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Each sheet of fabric shall contain the number of wires appropriate to its specified length, width, spacing and overhang dimensions. The number of broken welds shall not exceed either 1 % of the total number of cross-welded joints in the sheet or half the number of cross-welded joints along any one wire.

Fabric shall be free from any defect which can be shown to affect adversely the mechanical properties of the steel. Fabric including butt-welded wires shall be permitted and missing wires resulting from test sampling in accordance with clause 3 (Testing of WWR) shall not be considered as defects.

The longitudinal wires may be single or twin wires. The transverse wires shall be single wires. The dimensions of the fabric shall be specified as gross length in both directions. The permitted geometric deviation for fabric are:

length and width: ± 25 mm or ± 0.5 %, whichever is greater.

Wire spacing: ± 10 mm or ± 7.5 %, whichever is greater.

The recommended spacing of longitudinal wires is a multiple of 50 mm and preferably not less than 50 mm. The recommended spacing of transverse wires is a multiple of 25 mm and preferably not less than 25 mm.

5.18.3 Construction Handling, Shipping, Unloading and Storage of WWR

(i) Handling, Shipping, Unloading and Storage of WWR

Welded wire reinforcement sheets are bundled in quantities depending on size of sheets and corresponding weights in accordance with customers' requirements. The bundles are bound together using steel strapping or wire rod ties.

Once sheets are bundled, they are transported to storage or loading areas by forklift trucks or by overhead cranes or any the convenient method decided by the manufacturer. After the sheet bundles are loaded onto the flatbed trailers or vehicles, they are secured to the flatbed using chains and binders, nylon straps, steel strapping or a combination of these devices or any convenient method decided by the manufacturer.

The bundles of welded wire reinforcement sheets are unloaded at job site in the same way it was loaded. The manufacturer can choose any convenient method to unload the sheets at job site.

Welded wire reinforcement (WWR) shall be handled and stored in a manner that will prevent any accumulation of dirt, oil and paint. When placed in the works, it shall be free from dirt, oil, grease, paint, mill scale and loose or thick rust. If a rust stain is spotted on wwr, it shall be cleaned by brushing or soft grinding.

(ii) Installation Method

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The engineer or consultant or respective personnel from authority specifies the amount of reinforcement required and the correct position for the reinforcement within a structural element. To ensure proper performance of the reinforcement, it is essential that the welded wire reinforcement sheets be placed on supports to maintain their required position during concrete placement. The supports (either concrete blocks, steel or plastic “chair” devices, or a combination of these) must be appropriately spaced in order to work effectively. The concerned engineer from the implementing authority can take decision based on the site requirements.

5.18.3 Measurement

This work measured as provided above shall be paid for at the Contract unit price based on weight (in kilograms) of Welded wire reinforcement (wwr).

5.18.4 Payment

The payment shall be full compensation for furnishing and placing of Welded wire reinforcement (wwr) of any size and for all labor, unloading, placing, handling, shipment, equipment, tools, and incidentals necessary to complete the work prescribed in this Section.

Pay Item No.	Description	Unit Measurement
xxxxxxx	Welded Wire Reinforcement	kg

5.19. HIGH PERFORMANCE CONCRETE (HPC)

5.19.1 Description

High Performance Concrete (HPC) is a class of concrete engineered to meet enhanced performance requirements beyond conventional concrete, particularly in durability, workability, and strength for highway structures such as bridges, pavements, and incidental elements. HPC shall consist of a mixture of Portland cement, fine and coarse aggregates, water, mineral admixtures (e.g., fly ash, silica fume), chemical admixtures (e.g., high-range water reducers), and optional fibers, designed to achieve low permeability, high resistance to environmental degradation, and compressive strengths typically ranging from 40 MPa to 80 MPa at 28 days. The mix shall be self-consolidating where specified, with a target slump of 100-200 mm. HPC is suitable for elements requiring improved resistance chloride penetration, abrasion, and scaling, while maintaining uniformity and constructability. All mixes must comply with AASHTO and ASTM standards, with performance verified through trial batches approved by the Engineer.

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Note: Unless exclusively specified in this section, provisions of section 5.1 will remain applicable.

5.19.2 Materials

1. **Cement:** Portland cement conforming to AASHTO M85-23 Type I or II (low alkali if aggregates are reactive). Minimum content: 300-450 kg/m³, adjusted for admixtures. Certificates of compliance required.
2. **Fine Aggregate:** Clean, natural, or manufactured sand conforming to AASHTO M6-22, grading per AASHTO M43 or BS EN 12620:2002+A1:2008 (superseding BS 882:1992). Deleterious substances: clay lumps $\leq 0.25\%$, soft fragments $\leq 2\%$.
3. **Coarse Aggregate:** Crushed rock or gravel conforming to AASHTO M80-13 (R2021), maximum size 20 mm, grading per Table 5.1-1 with $\pm 5\%$ tolerances. Soundness loss $\leq 12\%$ per AASHTO T104-23.
4. **Water:** Potable or tested per AASHTO T26-23, re-tested quarterly or upon source change.
5. Mineral Admixtures:
 - Fly Ash: Class F or C per AASHTO M295-23, replacement 15-30% by cement weight.
 - Silica Fume: Per AASHTO M307-22 or ASTM C1240-20, replacement 5-10%.
 - Ground Granulated Blast Furnace Slag (GGBFS): Per AASHTO M302-23, replacement 20-50%.
6. **Chemical Admixtures:** High-range water reducers (HRWR) per AASHTO M194-22 Type F/G, dosage 1-2% by cement weight for water-cementitious materials ratio (w/cm) ≤ 0.35 .
7. **Fibers (Optional):** Steel or synthetic fibers per ASTM C1116-23, for enhanced tensile properties if specified in the Drawings.

All materials shall be tested per Standard Test Procedures (STP), with certificates submitted 28 days prior to use. No unauthorized substitutions permitted.

5.19.3 Mix Composition

The mix design shall target a w/cm ratio of 0.30-0.40, aggregate-paste volume ratio of 2.5-3.5, and efficiency factors for admixtures (e.g., silica fume $k=3-4$ for strength contribution). Use empirical trial mixes per ACI 211.4R-93 or modified Indian Standard (IS) method, correlating rheological parameters (yield stress < 50 Pa, plastic viscosity 20-50 Pa·s) with 28-day strength. Minimum cementitious content: 400 kg/m³. The Contractor shall submit mix designs 60 days prior for Engineer approval. Mix design preparation, testing and approval may be assisted by BRRL, RHD or any other suitable testing agency.

Table 5.13-1: Example HPC Mix Proportions (per m³ for 60 MPa target)

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Component	Quantity (kg)	Notes
Cement	350-400	Type I/II
Fly Ash/Silica Fume	50-100 / 20-40	Replacement levels
Fine Aggregate	600-800	Zone II grading
Coarse Aggregate	1000-1200	10-20 mm
Water	140-160	w/cm=0.35
HRWR	4-8 (L)	Adjust for slump ≥ 100 mm

Trial mixes required: Three batches, tested for slump (ASTM C143-20), air content (ASTM C231-22), and compressive strength.

5.19.4 Testing and Quality Control

- Fresh Properties:
 - Slump: ≥ 100 mm per ASTM C143-20; flow table per ASTM C230-21 if self-consolidating.
- Hardened Properties:
 - Compressive Strength: Per AASHTO T22-23/ASTM C39-21 (cylinders preferred; cube-cylinder conversion ~ 0.8 per BS 1881-120:2020). Target grades: 40-80 MPa at 28 days.
- Durability Tests:
 - Chloride Penetration: ≤ 1000 coulombs at 28 days per AASHTO T277-23/ASTM C1202-22 (very low permeability).
 - Scaling: Mass loss ≤ 0.5 kg/m² after 50 cycles per ASTM C672-12(R2021).
 - Abrasion: Relative volume loss index ≤ 2 per ASTM C779-19.
- **Sampling:** Every 50 m³ or daily, with statistical control per BS 5400-7:2020.
- **Rejection:** Batches failing strength ($<$ characteristic) or durability tests shall be rejected and removed at Contractor's expense.

5.19.5 Construction Procedures

Construction shall follow Section 5.1, with adjustments:

- **Mixing:** Use high-shear mixers for uniform dispersion of admixtures; batching tolerance $\pm 2\%$.
- **Placing:** Pumpable mixes preferred; vibrate to avoid honeycombing. For self-consolidating HPC, ensure flow without segregation.
- **Curing:** Moist cure ≥ 7 days or use curing membrane per AASHTO M171-22. Protect from temperature extremes.
- **Tolerances:** As per 5.1.3.2 (± 10 mm vertical for piers, ± 3 mm for critical elements). The Contractor shall submit a curing plan 28 days prior for approval.

5.19.6 Measurement and Payment

HPC shall be measured by cubic meter in place, as per approved Drawings.

Pay items:

- 05/13/01(a): Class 40 MPa HPC
- 05/13/01(b): Class 60 MPa HPC
- 05/13/01(c): Class 80 MPa HPC

Payment includes all materials, mixing, testing, curing, and incidentals; no separate payment for admixtures or trial mixes.

5.20. ULTRA-HIGH PERFORMANCE CONCRETE (UHPC)

5.20.1 Description

Ultra-High Performance Concrete (UHPC) is an advanced cementitious composite with exceptional mechanical and durability properties, suitable for bridge connections, overlays, precast elements, and seismic retrofits in highway structures. UHPC shall include fiber reinforcement (UHPRFC), achieving compressive strength ≥ 120 MPa, sustained tensile strength ≥ 5 MPa, and $w/cm < 0.25$. It provides optimized packing density, negligible permeability, and self-consolidating flow for thin sections or congested reinforcement. Proprietary pre-bagged mixes are allowed if meeting performance thresholds; non-proprietary ready-mixes require Engineer-approved designs. UHPC shall comply with AASHTO Guide Specifications for Structural Design with UHPC (1st Ed., 2024) and FHWA-HRT-19-011 guidelines.

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Note: Unless exclusively specified in this section, provisions of section 5.1 will remain applicable.

5.20.2 Materials

1. **Cement:** Portland cement per AASHTO M85-23, content 700-1200 kg/m³, high fineness (≥ 400 m²/kg).
2. **Fine Aggregate:** Silica sand or quartz flour, maximum size 0.6 mm, per AASHTO M6-22; no coarse aggregate.
3. **Water:** Potable or tested per AASHTO T26-23, w/cm ≤ 0.25 .
4. Mineral Admixtures:
 - Silica Fume: 150-250 kg/m³ per AASHTO M307-22/ASTM C1240-20.
 - Fly Ash or GGBFS: Optional, 100-250 kg/m³ per AASHTO M295-23/M302-23.
5. **Chemical Admixtures:** High-range water reducers (polycarboxylate-based) per AASHTO M194-22 Type F, dosage 20-40 L/m³; accelerators if specified.
6. **Fibers:** High-strength steel (tensile ≥ 2000 MPa) or polyvinyl alcohol (PVA), 2-3% by volume (150-200 kg/m³), length 6-13 mm, diameter 0.15-0.2 mm, per ASTM C1116-23.
7. **Other:** Nano-silica optional for enhanced early strength (≤ 30 kg/m³).

Materials shall be certified per ASTM C1856-17 (fabricating/test methods for UHPC). Fibers stored dry; reject if clumped or damaged. Certificates submitted 60 days prior.

5.20.3 Mix Composition

UHPC shall be optimized for dense microstructure, excluding coarse aggregates. Target flow: 200-250 mm slump per ASTM C1437-20 (dynamic). Example proportions (per m³ for 150 MPa target, based on FHWA/PCI guidelines):

Table 5.20-1: Example UHPC Mix Proportions (per m ³ for 150 MPa)		
Component	Quantity (kg)	Notes
Cement	700-900	High fineness
Silica Fume	150-250	Undensified preferred
Quartz Flour/Fine Sand	800-1000	Max 0.6 mm

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Water	150-200	w/cm=0.20-0.25
HRWR	20-40 (L)	Polycarboxylate-based
Steel Fibers	150-200	2% vol., aspect ratio 65-80

Trial mixes: Cast 2-inch cubes/cylinders; test at 4, 7, 14, 28 days. Minimum: 100 MPa at 4 days, 150 MPa at 28 days. Submit mix designs 60 days prior.

5.20.4 Testing and Quality Control

- **Fresh Properties:**
Flow: ≥ 230 mm per ASTM C1437-20; V-funnel time 4-10 s for self-consolidation.
- **Hardened Properties:**
 - **Compression:** Per ASTM C1856-17/AASHTO T22-23 (≥ 120 MPa cylinders; cubes $\sim 1.25\times$ factor per BS 1881).
 - **Tensile:** Sustained post-crack > 5 MPa per ASTM C1609-19 (first crack > 10 MPa, peak > 14 MPa).
- **Durability Tests:**
 - **Freeze-Thaw:** Durability factor 100% after 600 cycles per AASHTO T161-23.
 - **Chloride Penetration:** < 10 coulombs per AASHTO T277-23 (negligible).
 - **Abrasion:** Volume loss index < 1.7 per ASTM C779-19.

Oxygen Permeability: $< 10^{-20}$ m² per ASTM C1856-17.
- **Fiber Orientation:** Factor $K=0.8-1.2$ per AFGC/AASHTO, verified by image analysis if required.
- **Sampling:** Every 10 m³; heat curing optional (48-72°C for 48h) for accelerated strength.
- **Rejection:** Batches failing strength, tensile, or durability tests removed at Contractor's expense.

5.20.5 Construction Procedures

- **Mixing:** Use high-shear pan or forced-action mixers (mixing time 10-15 min). Verify fiber dispersion.
- **Placing:** Flow from one end for fiber alignment; minimal vibration for self-consolidating mixes.
- **Curing:** Initial moist/sealed cure for 24h; optional steam/heat (60-90°C) for 48h to achieve $> 80\%$ strength. Field-cast: Ambient cure ≥ 14 days.
- **Tolerances:** ± 2 mm for thin sections; align with 5.1.3.2 for other elements. The Contractor

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shall submit a detailed curing plan 28 days prior.

5.20.6 Measurement and Payment

UHPC shall be measured by cubic meter or lump sum for connections/overlays, as per Drawings. Pay items:

- 05/14/01(a): Structural UHPC (≥ 120 MPa)
- 05/14/01(b): Non-Structural UHPC (overlays, repairs) Payment includes fibers, curing, and incidentals; separate pay item for heat treatment if specified (05/14/02).

Notes:

- These specifications align with the provisions from Section 5.1 to Section 5.18, cross-referencing Section 5.1 for common procedures (e.g., formwork, tolerances).
- Standards updated to latest editions (as of August 27, 2025), addressing issues in original document (e.g., superseded AASHTO M85, BS 882).
- HPC and UHPC enhance durability for Bangladesh's humid, seismic conditions, supporting sustainable construction per FHWA and ACI guidelines.



DIVISION 6

MAINTENANCE

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6.1 REPAIR OF POTHoles BY BRICK FLAT SOLING (MACHINE MADEBRICKS)

6.1.1 Description

This item consists of providing single layer brick flat soling by machine made bricks on accepted damaged pavement bed for repair of potholes.



6.1.2 Construction Methods

Cutting Potholes edge into square shape by hand tools or excavator (if necessary) and leveling the bed by loose aggregate and sand (50% Khoa and 50% Sand) and then compacting by hand tools/rollers/plate compactors. The machine madebricks shall be laid flat on 75mm thick compacted aggregate sand layer over damaged pavement. Bricks shall be laid in a regular and uniform manner. Interstices of bricks shall be filled with sand, and water shall be applied by sprinkling. No bricks shall be laid on loose surface which has not been compacted to the required density or compaction criteria and no bricks shall be laid on any surface which has not been inspected and approved by the Engineer. Joint shall be repaired by bituminous materials with proper tack coat and sand.

6.1.2.1 Surface Tolerance

In those areas in which pavement is to be placed, any deviation in excess of 10mm from a straight edge, 3meters long applied to the surface parallel to the centerline of the road and 12mm from a 3 meters straight edge laid transversely, shall be corrected by removal, reshaping and relaying as per satisfaction of the Engineer.

6.1.3 Measurement

Repair of Potholes by Brick Flat Soling shall be measured in square meters of completed and accepted work.

6.1.4 Payment

This work, measured as described above shall be paid for at the unit rates detailed below. The rates shall include the supply of all required materials and all labor, equipment, tools and incidentals necessary to complete the works as specified.

Pay items shall be:

06/01/01	Repair of Potholes by Brick Flat Soling (machine madebricks)including 75mm thick aggregate sand layer	Square Meter



6.2 REPAIR OF POTHoles BY HBB (MACHINE MADE BRICKS)

6.2.1 Description

This item consists of providing single layer Herringbone bond (HBB) by machine made bricks on accepted damaged pavement bed for repair of potholes.



6.2.2 Construction Methods

Cutting Potholes edge into square shape by hand tools or excavator (if necessary) and leveling the bed by loose aggregate and sand (50% Khol and 50% Sand) and then compacting by hand tools/rollers/plate compactors. The machine made bricks shall be laid at an angle of 45° to the direction of the row, instead of horizontally. Alternate courses lie in opposing directions, resulting in a zigzag pattern on 75mm thick compacted aggregate sand layer over damaged pavement. Bricks shall be laid in a regular and uniform manner. Interstices of bricks shall be filled with sand, and water shall be applied by sprinkling. No bricks shall be laid on loose surface which has not been compacted to the required density or compaction parameter and no bricks shall be laid on any surface which has not been inspected and approved by the Engineer. Joint shall be repaired by bituminous materials with proper tack coat and sand.

6.2.2.1 Surface Tolerance

In those areas in which pavement is to be placed, any deviation in excess of 10mm from a straight edge 3 meters long applied to the surface parallel to the centerline of the road and 12mm from a 3 meters straight edge laid transversely, shall be corrected by removal, reshaping and relaying as per satisfaction of the Engineer.

6.2.3 Measurement

Repair of Potholes by Herringbone Bond Brick (HBB) Pavement shall be measured in square meters of completed and accepted work.

6.2.4 Payment

This work, measured as described above shall be paid for at the unit rates detailed below. The rates shall include the supply of all required materials and all labor, equipment, tools and incidentals necessary to complete the works as specified.

Pay items shall be:

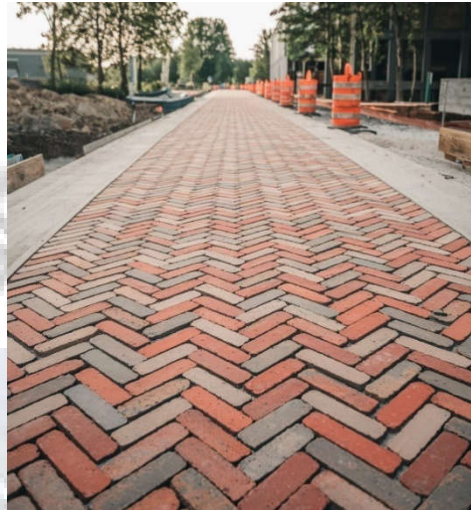
06/02/01	Repair of Potholes by Herringbone Bond Brick (HBB) (machine madebricks) including 75mm thick aggregate sand layer	Square Meter



6.3 HERRINGBONE BOND BRICK PAVEMENT WITH SAND CEMENT FILLER

6.3.1 Description

This work shall consist of a base composed of machine made machine made bricks, laid on edge in a herringbone pattern on 25mm cement concrete bed, placed on prepared single layer machine machine made brick flat soling in accordance with these specifications and to the lines, grades, levels, dimensions and cross sections shown on the drawings or as required by the Engineer.



6.3.2 Construction Method

The bricks shall be laid on edge in a single layer in a herringbone pattern to the lines, grades levels, dimensions and cross section shown on the drawings or as required by the Engineer. The edge of the layer shall be made with cut bricks to produce a line, which compatible with brick edging.

The joints shall be filled with sand cement (2:1) mortar.

6.3.2.1 Surface Tolerance

In those areas in which pavement is to be placed, any deviation in excess of 10mm from a straight edge 3 meters long applied to the surface parallel to the centerline of the road and 12mm from a 3 meter straight edge laid transversely, shall be corrected by removal, reshaping and relaying as per satisfaction of the Engineer.

6.3.3 Measurement

Brick on end edging shall be measured in linear meters of completed and accepted work. Brick flat soling and herringbone bond brick pavement shall be measured in square meters of completed and accepted work.

6.3.4 Payment

This work, measured as described above shall be paid for at the unit rates detailed below. The rates shall include the supply of all required materials and all labor, equipment, tools and incidentals necessary to complete the works as specified.

Pay items shall be:

06/03/01	Brick on end edging	linear Metre
06/03/02	Herringbone Bond Brick Pavement including sand cement (2:1) mortar	Square Meter

6.4 KHOA GROUTING

6.4.1 Description

This work shall consist of reshaping damaged/depressions area into regular shape, cleaning, applying tack coat, placing aggregate, applying bitumen, compacting aggregate and apply fine aggregate.

6.4.2 Materials

40mm downgraded dust free Brick Khoa from machine made brick plant having ACV greater than 30, LAA Value less than 35 and water absorption less than 15. Hot Bitumen of 60/70 grade heating up to 160°C. Stone Chips of 12 mm down grade.

6.4.2.1 Where Apply

Potholes and depression of greater than depth of 75 mm, broken edge repair. Normally apply on hard base layer or on bituminous layer. Not to apply on loose surface.

6.4.3 Construction Method

Cut the surface into regular shape. Clean the damaged surface properly. Apply hot bitumen of 1 kg/m² in the dustless dry aggregate layer not more than 100 mm thick in the proper level. Roll the aggregate properly. Apply hot bitumen of 2 kg/m². Applying stone chips for filling the gap over the bitumen rolling the surface. If depression or potholes are greater than 100mm thick then apply it into two layers.

6.4.4 Measurements

Measurement shall be taken as average thickness of depression of potholes area and volume of work done shall be measured by multiplying length width and depth of depression or potholes.

6.4.5 Payment

This work shall be included of cutting, cleaning, tack coat, placing of aggregate, rolling, applying bituminous layer, applying fine aggregate and finally rolling.

Pay items shall be:

06/04/01	Khoa Grouting	Cubic Metre

6.5 REMOVAL OF VEGETATION/JUNGLE/BUSH

6.5.1 Description

This item includes removal or cutting of vegetation or jungle (road side vegetation which obstructs vision of head on vehicles) by hand tool or cutting machine as per satisfaction of the engineer and dispose the waste into safe system and in a safe distance, in own arrangement, with Engineer's consent. Objective of this item shall be to remove undesirable roadside vegetation in order to maintain required sight distances, control roadside growth, ensure proper drainage, and to provide a reasonably neat appearance to the highway right-of-way.

6.5.2 Construction Method

All vegetation, including bushes, shrubs, jungle growth, and other greenery, shall be cleared and disposed of in an appropriate manner. This process may involve removal, mulching, or chipping, ensuring the highway right-of-way maintains a clean and aesthetically pleasing appearance. In areas where mechanical equipment cannot be used due to the presence of traffic, pedestrians, or nearby structures, manual hand-cutting tools shall be employed for vegetation control. The installation of temporary signage and traffic control measures is essential to ensure safety and smooth operations during the course of this work.

6.5.3 Payment

Payment shall be done by the area of removal or cutting. The removal of large quantities of brush, shrubs and small trees using hand tool or mechanically self-propelled equipment.

Pay item shall be:

06/05/01	Removal of Vegetation/Jungle/Bush	Square Meter

6.6 CLEANING GRASS, SOIL, SAND FROM ROAD MEDIAN

6.6.1 Description

This Item includes Cleaning Grass, Soil, Sand from Road Median, Road Side Vegetation which deposited on road median by hand tools, blower, cutter or other mechanical means and dispose the waste into safe system and safe distance, in own arrangement, with Engineer's consent.

6.6.2 Payment

Payment shall be done by the area of cleaning.

Pay item shall be:

06/06/01	Cleaning Grass, Soil, Sand from Road Median	Square Meter



6.7 REMOVAL OF UNSUITABLE/ HAZARDOUS MATERIALS

6.7.1 Description

This item includes excavation of unsuitable road side garbage,unsuitable debris, spoil and any other garbage. These materials shall be excavated and removed in full as directed by the Engineer. Garbage material includes domestic and industrial waste material, solid waste, liquid waste, food waste, hazardous substances etc. The Engineer may order to refill the excavated place with suitable soil, this backfilling procedure will follow the Division-2: Earthwork specifications.All of these excavated materials shall be kept and disposed in a safe system and safe distance, in own arrangement, as per satisfaction of the Engineer.

6.7.2 Materials

Generally road side garbage / unsuitable / hazardous materials those are caused due to unauthorized dumping by different entities or bodies or organizations.

6.7.3 Work Method

Excavate roadside garbage by excavator loading into dump truck, carrying materials to safe distance and dumping.

6.7.4 Measurement

Volume of excavated materials shall be measured into cubic meter depending on the length of disposal from the worksite

6.7.5 Payment

Payment shall be:

06/07/01	Up to 5 Km carried	Cubic Meter
06/07/02	Beyond 5 Km carried	Cubic Meter

6.8 MAINTENACE OF SHOULDER OR VERGE PROFILE CORRECTION

6.8.1 Description

This item consists of cutting / modifying / correcting earthen shoulder, filling nearby low shoulder and carrying excess materials into safe system and safe distance. The item also pertains to the scope of repairing or restoring washouts and low shoulders on paved or non-paved shoulders by adding new gravel or recycled asphalt or using existing material. Objective of this item is intended to ensure an acceptable shoulder surface, proper slope, and to provide a smooth transition from the edge of pavement to the toe of the embankment or right of way (ROW).

6.8.2 Materials

Generally earth materials to be cut from raised earthen shoulder or nearby sources.

6.8.3 Construction Method

Excavation of raised earthen shoulder should be done by hand tools/excavator then disposal of excavated materials by truck to safe system and safe distance. In case of nearby low earthen shoulder then filling by suitable materials. Finally rolling should be to the loose excavated / filling shoulder by roller.

6.8.4 Emergency Disaster Management

Erosion and washouts are the loss of shoulder material. This condition usually occurs during rain storms, flood, sea surges or extreme weather events. The most common problem areas are where guardrail has been installed, along and/or at the bottom of steep grades, and inside of turns. All washouts and low shoulders shall be repaired, low shoulders exist when the shoulder material is not flush with the edge of the pavement. This condition usually occurs due to insufficient granular material. All washouts adjacent to the edge of travelled lane and any low shoulders that pose a potential hazard to the traveling public shall be counter measured as soon as possible.

6.8.5 Measurement

Volume of excavated materials in cubic meter shall be measured depending on the length of the disposal from worksite

6.8.6 Payment

Payment shall be:

06/08/01	Up to 5 Km carried	Cubic Meter
06/08/02	Beyond 5 Km carried	Cubic Meter

6.9 CLEANING OF BRIDGE OR CULVERT OR UNDERPASS

6.9.1 Description

The work shall consist of cleaning of the dust, sand, soil, gravel, rubbish, vegetation, debris, other foreign materials etc. accumulated at different components of a bridge, namely deck surface, curbs and sidewalks, expansion joints, pier caps, abutment caps, trusses and their web members, lower flanges of beams and girders, wind bracings and drains curb or felloe guard; cleaning of parapet/guard; catch basin on the bridge and/or drainage pipe; expansion joints; steel or concrete girder ends including removal of obstruction to flow of small bridge, box or pipe culverts. The work shall also include cleaning of vegetation under/around the bridge, ramps, viaducts and slope retaining works.

6.9.2 Work Method

Overall methodology for the cleaning work including equipment and manpower mobilization, disposal plan, traffic diversion plan etc. shall have to be submitted to the Engineer for approval. For the cleaning of the bridge components, the water shall be clean and free from unwanted foreign materials such as sediments, salt contaminants, chemicals, grease, oil, rubbish and other substances which are harmful to the bridge components. The contractor shall obtain necessary approvals of the source of water to be used for cleaning. Engineer's approval shall be taken on the source and quality of water. All necessary tests shall be performed on water samples at laboratories to be specified by the Engineer, and test certificates shall be provided as required.

All accumulated foreign materials shall be removed from bridge sidewalks, bridge decks, top of curbs, beam flanges, gusset plates, abutment bridge seats, top of pier, truss joints, deck drain systems, and other locations specified and as directed by the Engineer, prior to cleaning with water pressure. Removal shall be performed using hand brooms, hand shovels, scrapers, vacuum cleaners or other methods acceptable to the Engineer. The removed materials shall be collected and disposed at an approved waste area in accordance with governing local regulations. Excavated, recovered or excess materials shall not be disposed into the river/canals/water bodies or on dry land portions below the bridge.

Salt contaminants, dirt, and other detrimental foreign matters shall be removed without damaging or peeling the paint from any structural steel. If high-pressure water is used, the maximum water pressure shall not be so high that any paint is damaged. The cleaning operation shall be discontinued if the foreign materials have not been easily removed or if cleaning operation is causing damage to existing paint coating. In this situation, the high-pressure water shall be adjusted to clean the surface without damaging the paint coating.

All deck drains and its accessories shall be flushed with high-pressure water after the accumulated foreign material has been properly removed. Drain systems may have to be disassembled to remove large blockages of accumulated foreign material. Should this be

necessary, these shall be returned to their original configuration immediately after cleaning. Drainage systems shall drain properly after cleaning.

The Contractor shall flush out the interior surfaces of all girders and truss members using high-pressure water. This flushing shall continue until such time that clear water is being draining out. The exterior surfaces of all truss members, miscellaneous structural steel connecting the truss members, and floor beam ends projecting outwardly from the row of exterior stringers shall be thoroughly washed down using high-pressure water.

The Contractor shall obtain approval of the source of water used. They shall use freshwater which is free of sediments and salt contaminants and be responsible for all expenses involved in securing the approved water.

The surface areas of a steel bridge should be cleaned and washed by brushing with freshwater or using high pressure water blasting, including the top and bottom flanges, webplates, diaphragms, lateral members and gusset plates. For convenience, inspection vehicle may be utilized to carry out cleaning of the bridge soffit.

All surface areas of the bridge deck should be cleaned including the curbs, expansion joints, drain pits and railings. This may be performed by manual shoveling/sweeping or using high pressure water blasting.

All areas under the superstructure should be cleaned, including the bearing shoe bed, concrete diaphragms and pier caps. This may be done by manual shoveling/sweeping or using high pressure water blasting. Accessing the top of piers, a higher ladder or hang ladder will be useful and an inspection vehicle can be utilized, if possible.

Vegetation shall be removed from the components of the bridges as well as from near the bridges if it is found that they affect the soundness of the structure in course of time.

6.9.3 Measurement and Payment

This payment shall be considered as full compensation for supplying all materials, labor, and equipment and for the performance of all works necessary for the flushing, washing, cleaning, and removal and disposal of all foreign materials and debris, in accordance with the contract documents.

Pay items shall be:

6/9/1	Cleaning of Bridge or Culvert or Underpass	Lump Sum

6.10 REMOVAL OF OBSTRUCTION TO WATERFLOW

6.10.1 Description

The work shall consist of removal of floating debris, drifting shrubs, weeds, vegetation, wood, etc. are transported by flowing water in the stream which pile up around the pier and adjacent to abutments and disposal to a designated area as per satisfaction of the Engineer

6.10.2 Work Method

The contractor shall take all necessary permissions for the works before commencement of activities. Permission from private property owners, if required, shall be taken lawfully when it is necessary to remove debris from public/private property.

Floating debris, driftwoods etc. shall be removed and disposed properly to a designated place. It may be necessary to cut the large driftwoods into pieces for disposal. Burning of the removed materials within the right of way is not permitted. The disposed material should be stockpiled at a designated area and dried. The contractor shall address all environmental issues associated with removal and disposal of debris from bridge sites. The water reservoir shall be kept intact after conducting this work.

6.10.3 Measurement and Payment

Pay items shall be:

6/10/1	Removal of Obstructions to the Waterflow	Lump Sum

6.11 REPAIRING OF PROTECTION WORKS DUE TO SCOURING

6.11.1 Description

The work shall consist of restoration of missing stones/bricks from masonrywork, gabion mattress and protection works, caused by the scouring effect of flooding.

6.11.2 Work Method

(a) Filling material

Partially or fully missing bricks / stones in the damaged masonry work shall be replaced by installing new brick / stone masonry following the alignment and dimensions indicated in the drawings or as per instruction of the Engineer.

(b) Mortar masonry

All loose, imperfect or unsound bricks / stones and mortar joints, panels, etc. in the existing works shall be removed. The substrata shall then be compacted to achieve a sound base to receive the new bricks/stones. The slope line shall be carefully prepared and repair work shall be executed in accordance with the drawings and as per site requirements.

(c) Supplemental masonry

Where new stone masonry is placed into the existing masonry wall, joints shall be partially or completely set. Exposed surface of the existing stone masonry shall be cleaned with wire brush and lightly moisten so as to attain best possible bonding with the new work.

(d) Curing

After laying of the bricks / stones into the existing mortared masonry work, curing with water shall be done after the initial setting of the mortar at the joints, and shall be continuously cured for 7 days.

6.11.3 Measurement and Payment

This work will be paid based on a unit price per cubic meter or lump-sum to compensate for cutting, loading, hauling, disposing of existing stone/brick/concrete block masonry work and subsequent cleaning etc. at each location and for all labor, equipment, tools, and other necessary accessories to complete the work.

Pay items shall be:

6/11/1(a)	Repairing Stone masonry	Cubic metre (m ³)
6/11/1(b)	Repairing Stone masonry	Lump sum (LS)
6/11/2(a)	Repairing Mortar masonry	Cubic metre (m ³)
6/11/2(b)	Repairing Mortar masonry	Lump sum (LS)

6.12 REPAIR OF GABION MESH

6.12.1 Description

The work shall consist of restoration of the Gabion mattresses used for protection of river banks, bed as well as for protection of abutments and piers by replacing the damaged wires.

6.12.2 Work Method

Proper access arrangement for the work shall be ensured. The damaged/unacceptable portions of gabion wires shall be cut and removed carefully. While removing the damaged wires, care shall be exercised not to disturb the existing portion of the gabion work which is in intact condition.

Any missing infill material (stones/bricks/concrete blocks) in the gabion mattress shall be replaced by the same infill material as per the specification by inserting through the openings made by cutting the damaged wires as mentioned above. The new infill material shall be properly inserted and made to level with the existing surface so that the new work does not unduly protrude beyond the existing surface.

New gabion wire mesh shall be placed over the existing damaged mesh. The new mesh shall be tied to the existing with steel wires as used in original gabion works. Care shall be taken to fully cover the damaged portions leaving no space for the infill materials to come out. Upon completion of works, all material, tools and equipment shall be removed from the site.

6.12.3 Measurement and Payment

This work shall include full compensation for cutting, loading, hauling, disposing of existing stone/brick/concrete block masonry work and subsequent cleaning, etc. at each location and for all labor, equipment, tools, and other necessary accessories to complete the work.

Pay items shall be:

6/12/1(a)	Repair of gabion mesh	Cubic meter (m ³)
6/12/1(b)	Repair of gabion mesh	Lump sum (LS)

6.13 PATCHING OF CONCRETE SPALLING

6.13.1 Description

The work shall consist of patching of spilling including minor honey comb and potholes in deck. The will be applicable to spilling of concrete having width less than 300 mm and depth less than 50mm.

6.13.2 Work Method

The work shall comprise application of polymer cement repair mortar on the spilled portion of concrete after treating the area with suitable bonding agent and after applying anticorrosion paint on the surfaces of the corroded rebar, if any. The work requires adequate curing.

6.13.2.1 Material specification

The material shall be approved by the Engineer through mill certificate of the supplier.

(a) Polymer Cement

Polymer cement mortar shall conform to the requirements of the specifications shown in Table 9-1 or equivalent ASTM Specifications.

Table 6.13-1 Specification of Polymer Cement for Patching

Property	Test Method	Specification
Initial setting time	-	above 60 minutes
Shrinkage	ASTM D2566	below 0.05 %
Thermal expansion	ASTM C531	2.0×10^{-5} mm/mm/°C
Slant shear bond to concrete	ASTM C882	Concrete failure above 15 N/mm ²
Compressive strength	ASTM D695M	above 20 N/mm ²

(b) Epoxy bonding agent

The epoxy bonding agent to concrete surface shall conform to the requirements of the specification indicated in Table 6.13-2. (Anti-corrosion zinc rich primer shall be applied to exposed rebar).

Table 6.13-2 Compressive strength ASTM D695M 70 N/mm²

Property	Test Method	Specification
Compressive strength	ASTM D695M	70 N/mm ²
Flexural strength	ASTM D790M	40 N/mm ²
Tensile strength	ASTM D638M	30 N/mm ²
Tensile shear bond to steel	ASTM 1002	15 N/mm ²
Slant shear bond to mortar	ASTM C882	15 N/mm ²
Bond Strength of Cured Concrete to Fresh Concrete	ASTM D7274	15 N/mm ²

(c) Zinc Rich Primer

The zinc rich primer to rebar shall be in accordance with the requirements of the specifications in Table 6.13-3.

Table 6.13-3 Specification of Zinc Rich Primer for Rebar

Property	Test Method	Specification
Gloss @ 60°Angle	ASTM D 523	Flat
Adhesion	ASTM D 3359	Minimum 3A
Salt Spray Resistance	ASTM D3-37	Excellent
%Zinc by Weight in Dried FilmTest	-	87.5±2 percent

6.13.2.2 Work requirement

(a) General

Patching repair works using Portland cement mortar shall be carried out in accordance with provisions of relevant standards and manufacturer's specifications. Patching, as a minor pair work, should be carried out using an appropriate means to access the repair area before the defect worsens. Patching repair work method using polymer cement mortar shall be carried out as follows.

(b) Marking of patching area

The surface area to be patched will be evaluated using hammer for hollow sounding delaminated area (or by using instruments to detect unsound concrete). The area to be patch-repaired will be marked with paint or marker and complete coverage of the Damage area will be ensured.

(c) Tipping damaged concrete off

Using a small sledge hammer and chisel, all damaged concrete at the edges and corners of area to be repaired shall be removed. Loose debris shall be removed using a wire brush. Care should be taken to ensure that no reinforcement is damaged. Surface shall be cut to expose the reinforcement and to reach the sound concrete substrate, without breaking the concrete behind the reinforcement. If rebar is exposed, anticorrosion agent coating should be applied on the bar surface prior to patching. All works shall be subjected to the approval of the Engineer. Patch areas that are within 600 mm of each other should be combined into a single large patch. If necessary, formwork around the damaged concrete shall be provided to straighten the edges of the damaged section.

(d) Coating tipping area

Concrete surfaces to receive repair mortar shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss. The clean and dust free surface shall then be coated by a bonding primer. Care shall be taken to ensure that vibration associated with the repair works does not cause delimitation of existing adjacent plaster or concrete.

(e) Applying bonding agent and anti-corrosion paint

Bonding agent to the damaged area shall be applied in order for the patch material to adhere. Additionally, concrete nails/bids may be set to reinforce the repair. If rebar is exposed, anticorrosion coating should be applied on the bar surface prior to patching.

(f) Patching mortar

The mortar mix shall be prepared in a bucket using equipment approved by the Engineer. A trowel shall be used to spread fresh mortar over the area, covering the concrete nails driven halfway in the old concrete. The mortar shall be leveled by using a trowel. Polymer cement mortar is suitable for both vertical and horizontal surface applications, with a thin coating of up to 15 mm.

(g) Finishing

As may be required, the mortar surface can be smoothed using a trowel or broom finish. The texture of the finish of the final repair mortar layer shall match the finish of the existing surface. The repair mortar application shall be built up to the original surface profile in layers not exceeding 20 mm with the final layer not exceeding 15 mm, unless otherwise recommended by the manufacturer and approved by the Engineer. The Engineer may approve repair mortar application thickness of up to 50 mm for light weight mortars, provided the mortar manufacturer furnishes technical data to justify a layer thickness of greater than 20 mm.

(h) Curing

All types of concrete repair with repair mortar need thorough and continuous curing to develop strength and impermeability. Curing also minimizes drying shrinkage while bond strength is developing. Curing of the repair mortar shall be in accordance with the manufacturer's instructions related to the polymer modified additive. Where curing agents are specified by the manufacturer, they shall be applied immediately after the surfaces have been scarified for the next repair mortar layer, or troweled to a finish.

6.13.3 Measurement and Payment

Area prepared for patching shall be measured in square meter after removal of concrete of required thickness over the marked area of delaminated concrete identified by the Engineer.

Payment shall be made based on per square meter rate which shall include identification and removal of deteriorated concrete, cleaning and preparation of surface to receive repair mortar, furnishing and placing of all materials including finishing, curing, formwork, labor, equipment, tools and necessary access arrangement, as well as removal of formwork, staging, scaffolding and all other temporary works after completion, complete as specified and directed by the Engineer.

Pay items shall be:

6/13/1	Patching	Square meter (m ²)

6.14 TOUCHUP PAINTING

6.14.1 Description

The work shall comprise touchup painting on steel members at localized areas including surface preparation and other associated works. This section shall cover only painting on relatively less affected areas which can be carried out with the use of machine tools / hand tools. Painting of larger areas requiring sand blast cleaning which should be carried out in accordance with the specifications covered under major repairs.

6.14.2 Work Method

6.14.2.1 Application criteria

Touchup painting shall be done locally on partially rusted steel surfaces. Depending on the area affected by corrosion, two different surface preparations will be needed.

Table 6.14-1 Degree of rusting and surface preparation

Affected Area	Description of degree of rusting	Surface preparation
10-20 %	Grade-1: Corrosion is partially visible but not severe. Peeled-off coating film is partially visible	Remove old coating film, rust with disk grinder, scraper and wire brush
20-30%	Grade-2: Corrosion is partially severe on steel surface and coating film is almost visible but partially deteriorated due to corrosion	Remove old coating film, rust with scraper and wire brush partially revealing the steel texture

If the paint condition is identified as Grade-1 (affected surface 10-20%), aluminum paint shall be applied with a similar shade. Where condition of paint is evaluated as Grade-2 (affected surface 20-30%) with loss of section within 20%, special anticorrosion paint shall be applied to restrict corrosion from progressing further.

Galvanized and heavily corroded steel surfaces shall also be treated with special anticorrosion paint systems. Patch repair with ordinary aluminum paint is not suitable for repair of corrosion affected galvanized steel surfaces (Old steel truss bridges manufactured in USA are made up of galvanized metal). As shown in the photos, special anticorrosion paint shall be applied to heavily corroded steel portions.

6.14.2.2 Material

Aluminum paint material shall be in accordance with the manufacturer's specifications and as approved by the Engineer. For special anticorrosion paint, the materials shall satisfy the test requirements indicated in the relevant ASTM specifications as follows.

Table 6.14-2 Specification of Aluminum paint

Tests	Test Reference	Specifications
Adhesive test	ASTM D7234	7days 1.0 N/mm ² , 28days 1.5 N/mm ²
Elongation	ASTM C190	7days 0.40 %, 28days 0.40 %
Saltwater test	ASTM D6943	No defection

6.14.2.2 Work Requirement

(a) Scaffolding

Scaffolding shall be installed for close access to the corrosion affected surfaces of the steel members to be repaired. Standard scaffoldings may be used, however mobile scaffolding/inspection vehicle may be found suitable as it allows for free movement in most cases and provides access with convenience to various parts of a bridge, particularly for bridges with high elevation or deep river crossings.

(b) Preparation of Steel Surface

Surface preparation shall conform to the paint manufacturer's specifications. Hand or power tools shall be applied for cleaning the surface. Grooves and ridges formed on the affected surface shall be removed with power grinder. Where appropriate, as an alternative, epoxy resin filler may be used to fill the surface to a smooth and even finish. Where depth of roughness is within 0.5 mm, paint adequacy and durability can be achieved without application of multiple coats of surface leveling paints. Thickness of each coat shall not exceed the limiting value recommended in the paint manufacturer's specifications.

Application of aluminum paint material shall be in accordance with the manufacturer's specifications and as approved by the Engineer.

(c) Application of Touchup Paint

Paint shall be applied with brush or roller. The paint shall be applied in such a way that a uniform and smooth surface is formed without wrinkles, runs, streaks, sags, or any other defects. Components of the paint shall be mixed in accordance with the manufacturer's instructions and the application shall also conform to such instructions and specifications. Paint shall be applied immediately after the surface preparation, preferably within 4 hours.

Total dry film thickness for special anticorrosive paint shall be 500 m (equivalent 1.5 kg/m²) consisting of two layers of coating as follows:

-Layer-1: 250 m

-Layer-2: 250 m

Anticorrosion paint shall be applied in accordance with the stipulations of paint manufacturer's specifications. Minimum total film thickness for aluminum paint shall be not less than 125 m.

Ronal paint is recommended for galvanized member touchup painting.

Total dry film thickness for Ronal paint shall be 80 m (equivalent 0.5kg/m²) consisting of two layers of coating as follows:

-Layer-1: 40 m

-Layer-2: 40 m

Ronal paint shall be applied in accordance with the stipulations of paint manufacturer's specifications.

6.14.3 Measurement and Payment

The work shall be measured as the accepted surface area treated and painted, in square meters.

Payment shall be made based on unit price per square meter area of field touchup painting complete in all respect and approved, including all labor, services of technical service advisor, equipment, tools, materials and work incidentals including all necessary storage and hauling to and from the bridges as repaired, and collection and storage of all materials within the work area.

Pay items shall be:

6/14/1	Touchup painting	Square metre (m ²)

6.15 CRACK INJECTION

6.15.1 Description

The work shall comprise crack repairs to any concrete structures, particularly to deck slab. The works include preparation of concrete surface, insertion of pipe fittings bonded with adhesive, injection of epoxy, curing and conducting performance test. Crack injection for concrete requires highly skilled process and its effectiveness depends mostly on the proficiency of the certified technician. The technicians should be qualified based on his experience and approved by the Engineer-in-Charge.

6.15.2 Work Method

6.15.2.1 Material

The material shall be approved by the Engineer through Manufacturer's Test Certificate (MTC) from the supplier.

(a) Epoxy Resin

The epoxy resin shall be compatible with the concrete of structure and shall have the properties shown in Table 6.15-1. Testing of said properties shall be in accordance with the relevant standards shown in Table 6.15-1, or equivalent ASTM Specifications.

Table 6.15-1 Specification of Epoxy Resin (for Deck Slab)

Property	Test Method	Unit	Specification
Viscosity (cPs)	ASTM D2393	mPa.s	500/below
Potlife	-	min	30
Specific Gravity	ASTM D792	-	3.30 ± 0.1
Compressive Strength	ASTM D695M	N/mm ²	20 /above
Flexural Strength	ASTM D790M	N/mm ²	10/above
Tensile Shear Bond to Steel	ASTM D1002	N/mm ²	15 /above
Slant Shear Bond Strength to Concrete	ASTM C882	N/mm ²	15/above
Bond Strength to Concrete Dry / Wet	ASTM D7234	N/mm ²	1.5

(b) Sealant

The epoxy-based sealant material shall be compatible with the injection material and shall have the properties listed in Table 6.15-2 below. Testing of materials shall be in accordance with the listed standards or equivalent ASTM Specifications.

Table 6.15-2 Specifications of Sealant (Putty) for Crack Injection (for Deck Slab)

Property	Test Method	Unit	Specification
Specific Gravity	ASTM D792	-	1.50±0.30
Bond Strength	ASTM C882	N/mm ²	15/above
Compressive Strength	ASTM D695M	N/mm ²	50 /above
Flexural Strength	ASTM D790M	N/mm ²	15 /above
Tensile Shear Bond Strength	ASTM D1002	N/mm ²	10 /above

6.15.2.2 Work requirement

The Contractor shall submit the Work Procedure/Statement to the Engineer for approval comprising material approval, injection procedure, quality assurance plan, equipment deployment, skilled/semi/unskilled manpower, diversion planning, or any other pertinent documents before commencement of the work.

(a) Clean the cracks

All loose debris such as dirt, concrete fine particles and contaminants (oil, grease, etc.) shall be removed from the cracks using high-pressure water, or special solvent. The residual water or solvent in the crack shall be blown away with filtered (dust and oil free) compressed air and adequate time will be allowed for drying air.

The intention of this work is to fill and seal these cracks, particularly those found on concrete bridges. The extent of the cracks shall be indicated by the Contractor and shown on drawings. The detail of the quantities shall be marked out on the concrete elements and agreed with the Engineer prior to proceeding. The Engineer may adjust the extent of the work as the project proceeds, based on actual conditions.

Loose or spilled concrete, grease, traces of paints, oil or other contaminants shall be marked out and removed using wire brushes, grinding wheels or power brush.

All cracks shall be thoroughly cleaned using clean, oil-free compressed air. Both the concrete surface and the cracks shall be allowed to dry thoroughly before commencing the crack injection.

(b) Adhesion of pipe fitting

The terminal of the injector shall be connected to the pipe fittings. Pipe fittings are bonded with the adhesive to the crack center for injecting epoxy. Spacing of the pipes varies between 150mm to 500 mm, depending on the width and depth of the cracks. The first and last pipe fitting shall be set at or near the bottom and top respectively. The pipe fittings shall be fixed at certain intervals along the length of each crack. The distance between each fitting shall be as shown on the drawings, considering the width and depth of crack, for approval of the Engineer.

The surface sealant shall be moisture tolerant putty with good adhesion to concrete. This is supplied in two components namely, the base resin and the hardener. These are weighed according to the specified mix proportions of the manufacturer. The mixing process is continued until a uniform paste is obtained. The mixed surface sealant shall be applied to the

metal base of each pipe fitting. They shall be pressed firmly into place and held until secured. In this way, all the fittings shall be fixed along the length of the crack. The surface of the cracks between the fittings shall be sealed with a band of surface sealant, measuring 50 mm wide and 2 to 3 mm thick. A complete seal shall be made around the metal bases of each pipe fitting. The repaired cracks shall be allowed to cure for at least 12 hours.

(c) Epoxy Injection

Epoxy shall be injected using air-activated injecting guns. Injection is performed on the pipe fitting. Duration of the injection operation shall be in accordance with the supplier's instructions.

If the crack is vertical, the injection of epoxy shall be commenced at the lowest pipe fitting, until the epoxy exudes from the pipe fitting above. For horizontal cracks, the injection shall be carried out from one end of the crack to the other, in a similar manner. Using a 5 cm width strap, epoxy sealant shall be applied on the area around the pipe fitting and cracks allowing it to harden.

Each crack shall be treated in a single, continuous operation. Sufficient materials shall therefore be readily available prior to the commencement of work. The preparation, mixing and application of the materials shall be undertaken in strict compliance with the manufacturer's recommendations and approved by the Engineer. Before the work commences, the Contractor shall ensure that all necessary tools and equipment are on site.

The materials shall not be used without the approval of the Engineer when the ambient temperature is at or below 5 degree Celsius or is above 35 degree Celsius. Only intact package of epoxy resin shall be used for each injection purpose. No part packs or on-site batching shall be allowed under any circumstances.

In all operations of storage, mixing and application, the Contractor shall comply with the health and safety standards of the Engineer and the relevant governing rules and regulations as well.

(d) Curing

The epoxy system shall be allowed to cure undisturbed for twenty four (24) hours. The pipe fittings and bands of surface sealant shall then be removed. Any damaged areas shall be made good to the satisfaction of the Engineer-in-Charge.

(e) Performance Test

Low Frequency Pulse Velocity Ultrasonic Inspection will be determined if the epoxy resin has penetrated the full depth of the crack. If incomplete penetration is revealed from this test, the work has to be repeated on the Contractor's expense.

6.15.3 Measurement and Payment

The method of measurement to determine payment for the crack injection works on cracks shall be based on the total the lengths of the cracks or the works as lump sum, which are identified by the Engineer.

The contract price paid per meter or in lump sum for this work item shall include full compensation for supplying all labor, materials, tools, equipment, and incidentals, and for performing all the works involved in the preparation and injection of epoxy on cracks in the existing concrete completely in place as shown on the plans and as specified in the standard specifications, special provisions and as directed by the Engineer-in-Charge.

Pay items shall be:

6/15/1	Crack Injection	Linear Meter (m)
6/15/2	Crack Injection	Lump Sum

6.16 CRACK FILLING

6.16.1 Description

The work shall comprise crack repairs to concrete structures by filling the cracks with flexible sealant. Crack widths should be more than 0.5 mm with depth of less than 300 mm.

6.16.2 Work Method

6.16.2.1 Material

The material shall be approved by the Engineer through Manufacturer's Test Certificate (MTC) from the supplier. Testing of materials shall be in accordance with the relevant standards shown or equivalent ASTM Specifications.

(a) Epoxy bonding primer

Epoxy bonding primer shall conform to the Specifications as shown in Table 6.16-1 below.

Table 6.16-1 Specifications of Epoxy Bonding Primer

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM D695M	N/mm ²	70
Flexural Strength	ASTM D790M	N/mm ²	40
Tensile Strength	ASTM D638M	N/mm ²	30
Tensile Shear Bond to Steel	ASTM D1002	N/mm ²	10
Slant Shear Bond to Mortar	ASTM C882	N/mm	15

(b) Sealant

The epoxy-based sealant material shall be compatible with the injection material and shall have the properties listed in Table 6.16-2.

Table 6.16-2 Specification of Epoxy Based Sealant

Property	Test Method	Unit	Specifications
Specific Gravity	ASTM D792	-	1.5±0.3
Elongation	ASTM D638	%	50
Bond Strength to Concrete Dry /Wet	ASTM C882	N/mm ²	3.0

6.16.2.2 Work requirement

The Contractor shall submit the Work Procedure/Statement to the Engineer for approval comprising material approval, injection procedure, quality assurance plan, equipment deployment, skilled/semi/unskilled manpower, diversion planning, or any other pertinent documents before commencement of the work.

(a) Preparation of concrete

All loose debris such as dirt, concrete fine particles and contaminants (oil, grease, etc) shall be removed from the cracks using high-pressure water, or special and effective solvent. The

residual water or solvent in the crack shall be blown away with filtered (dust and oil free) compressed air and adequate time shall be allowed for drying air. The intention of this work is to fill and seal these cracks, particularly those found on concrete bridges. The extent of the cracks shall be indicated by the Contractor and shown on drawings. The detail of the quantities shall be marked out on the concrete elements, and agreed with the designated Engineer prior to proceeding. The Engineer may adjust the extent of the work as the project proceeds, based on actual conditions.

Loose or spilled concrete, grease, traces of paints, oil or other contaminants shall be marked out and removed using wire brushes, grinding wheels or power brush as cleaning devices.

All cracks shall be thoroughly cleaned using clean, oil-free compressed air. Both the concrete surface and the cracks shall be allowed to dry thoroughly before commencing the injection.

(b) Preparation of Groove

Using a concrete saw, hand tools or pneumatic tools, a minimum 10 mm wide x 10 mm deep V-groove or U-groove shall be prepared at the surface along the crack. The groove shall be cleaned with an oil free air jet or wire brush before placing the bonding coat.

(c) Applying bonding coat

The concrete surface of groove to which the bonding coat is to be applied shall be wet using potable water to achieve a moisture condition such that the concrete will not absorb moisture from the mortar. The wetting period will depend upon the substrate condition and the bonding coat manufacturer's recommendations, subject to Engineer's satisfaction.

The surface shall then be left wet until the free water has evaporated before the bonding coat is applied. Using a brush, the coat shall be applied to the exposed concrete surface.

(d) Caulking epoxy sealant

The mixed sealant shall be applied into the groove along the cracks by a caulking gun. A complete seal shall be made around the metal bases of each port. The applied sealant as a caulking shall be allowed to cure for at least 12 hours.

The sealant material shall be selected in consideration with the crack movement which should be calculated considering the applied loads, shrinkage and temperature variations.

The Contractor shall propose suitable sealant material based on the study on the crack movement, subject to Engineer's approval. The preparation, mixing and application of the sealant materials shall be undertaken in strict accordance with the manufacturer's recommendations.

The Contractor is to ensure that all necessary tools and equipment are on site until the works commence. In all operations of storage, mixing and application, the Contractor shall comply with the health and safety recommendations of the Engineer and the relevant governing rules and regulations.

(e) Curing

After the crack is sealed the sealant shall be allowed to cure for twelve (12) hours and shall be let undisturbed for this time.

(f) Performance test

Low Frequency Pulse Velocity Ultrasonic Investigation shall be used to determine if the epoxy sealant has penetrated to the base of the groove. If incomplete penetration is revealed by investigation, such conditions shall be reworked at cost to the Contractor.

6.16.3 Measurement and Payment

The method of measurement to determine payment for the Filling works shall be based on the total lengths of the cracks or works as lump sum, which are identified by the Engineer-in-Charge.

The contract price paid per meter or lump sum for this work item shall include full compensation for supplying all labor, materials, tools, equipment, and incidentals, and for performing all the works involved in the preparation and injection of epoxy on cracks in the existing concrete, completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

Pay items shall be:

6/16/1	Crack Filling	Linear Meter (m)
6/16/2	Crack Filling	Lump Sum

6.17 CONCRETE SURFACE REPAIR BY HAND APPLIED MORTAR

6.17.1 Description

The works shall include Hand applied Mortar (Patching) repair performed to restore small areas where sound concrete is damaged by spilling, scaling and/or impact. The patch thickness is limited to a maximum of 100 mm depth of hollow surface.

The work shall be applied to defects without exposed rebar's [Hand applied Mortar (A)] and/or to surfaces with exposed rebar's [Hand applied Mortar (B)].(B) is applied to surfaces with exposed rebar's.

6.17.2 Work Method

6.17.2.1 Material

The material shall be approved by the Engineer through Manufacturer's Test Certificate (MTC) from the supplier. Testing of materials shall be in accordance with the relevant standards shown or equivalent ASTM Specifications.

(a) Epoxy bonding primer

Epoxy bonding primer shall conform to the Specifications as shown in Table 6.17-1 below.

Table 6.17-1 Specifications of Epoxy Bonding Primer

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM D695M	N/mm ²	70
Flexural Strength	ASTM D790M	N/mm ²	40
Tensile Strength	ASTM D638M	N/mm ²	30
Tensile Shear Bond to Steel	ASTM D1002	N/mm ²	10
Slant Shear Bond to Mortar	ASTM C882	N/mm	15

(b) Sealant

The epoxy-based sealant material shall be compatible with the injection material and shall have the properties listed in Table 6.17-2.

Table 6.17-2 Specification of Epoxy Based Sealant

Property	Test Method	Unit	Specifications
Specific Gravity	ASTM D792	-	1.5±0.3
Elongation	ASTM D638	%	50
Bond Strength to Concrete Dry /Wet	ASTM C882	N/mm ²	3.0

6.17.2.2 Work requirement

The Contractor shall submit the Methodology (procedures) of the Work to the Engineer for his review and approval before commencement of the work.

(a) Preparation of concrete

All loose debris such as dirt, concrete fine particles and contaminants (oil, grease, etc) shall be removed from the cracks using high-pressure water, or special and effective solvent. The

residual water or solvent in the crack shall be blown always with filtered (dust and oil free) compressed air and adequate time shall be allowed for drying air. The intention of this work is to fill and seal these cracks, particularly those found on concrete bridges. The extent of the cracks shall be indicated by the Contractor and shown on drawings. The detail of the quantities shall be marked out on the concrete elements, and agreed with the designated Engineer prior to proceeding. The Engineer may adjust the extent of the work as the project proceeds, based on actual conditions.

Loose or spilled concrete, grease, traces of paints, oil or other contaminants shall be marked out and removed using wire brushes, grinding wheels or power brush as cleaning devices.

All cracks shall be thoroughly cleaned using clean, oil-free compressed air. Both the concrete surface and the cracks shall be allowed to dry thoroughly before commencing the injection.

(b) Preparation of Groove

Using a concrete saw, hand tools or pneumatic tools, a minimum 10 mm wide x 10 mm deep V-groove or U-groove shall be prepared at the surface along the crack. The groove shall be cleaned with an oil free air jet or wire brush before placing the bonding coat.

(c) Applying bonding coat

The concrete surface of groove to which the bonding coat is to be applied shall be wet using potable water to achieve a moisture condition such that the concrete will not absorb moisture from the mortar. The wetting period will depend upon the substrate condition and the bonding coat manufacturer's recommendations, subject to Engineer's satisfaction.

The surface shall then be left wet until the free water has evaporated before the bonding coat is applied. Using a brush, the coat shall be applied to the exposed concrete surface.

(d) Caulking epoxy sealant

The mixed sealant shall be applied into the groove along the cracks by a caulking gun. A complete seal shall be made around the metal bases of each port. The applied sealant as a caulking shall be allowed to cure for at least 12 hours.

The sealant material shall be selected in consideration with the crack movement which should be calculated considering the applied loads, shrinkage and temperature variations.

The Contractor shall propose suitable sealant material based on the study on the crack movement, subject to Engineer's approval. The preparation, mixing and application of the sealant materials shall be undertaken in strict accordance with the manufacturer's recommendations.

The Contractor is to ensure that all necessary tools and equipment are on site until the works commence. In all operations of storage, mixing and application, the Contractor shall comply with the health and safety recommendations of the Engineer and the relevant governing rules and regulations.

(e) Curing

After the crack is sealed the sealant shall be allowed to cure for twelve (12) hours and shall be let undisturbed for this time.

(f) Performance test

Low Frequency Pulse Velocity Ultrasonic Investigation shall be used to determine if the epoxy sealant has penetrated to the base of the groove. If incomplete penetration is revealed by investigation, such conditions shall be reworked at cost to the Contractor.

6.17.3 Measurement and Payment

The method of measurement to determine payment for the filling works shall be based on the total lengths of the cracks or as lump sum, which are identified by the Engineer.

The contract price paid per meter or lump sum for this work item shall include full compensation for supplying all labor, materials, tools, equipment, and incidentals, and for performing all the works involved in the preparation and injection of epoxy on cracks in the existing concrete, completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

Pay items shall be:

6/17/1	Concrete Surface Repair by Hand Applied Mortar	Linear Meter (m)
6/17/2	Concrete Surface Repair by Hand Applied Mortar	Lump Sum

6.18 DUST CONTROL

6.18.1 Description

The application of dust control product to control airborne dust created by traffic. To mitigate the negative effect of airborne dust with respect to visibility and nuisance dust.

6.18.2 Work Method

The work for this activity involves the contracted supply and/or mechanical application of water over the road surface, typically using a water bowser. To enhance stabilization, dust control agents such as calcium or magnesium chloride can be mixed with the water and sprayed. In areas with higher traffic volumes or where additional stabilization is required, increased amounts of water may be applied based on local conditions.

6.18.3 Measurement and Payment

This work shall be paid based on a unit price per kilometer to fully compensate for equipment, materials, labours, efforts and other necessary accessories to complete the work.

Pay items shall be:

6/18/1	Dust Control	Kilometer

6.19 ASPHALT PATCHING

6.19.1 Description

Asphalt patching involves repairing surface defects in paved areas using hot or cold mix asphalt, applied either manually or with an automatic/semi-automatic patching machine. This process covers patching potholes, depressions, pavement edge defects, distressed areas, and asphalt gutters. The main goal is to remove traffic hazards by filling holes, leveling surface depressions, and improving the overall riding quality of the pavement.

6.19.2 Work Method

For pothole repairs, miscellaneous patching, and asphalt gutter installation, any preparatory tasks, including the removal of asphalt and/or gravel and the placement of granular material up to 300 mm deep, are part of this activity. Cold mix asphalt is typically used when hot mix asphalt is unavailable. Potholes that do not meet the minimum criteria outlined in the "Pothole Criteria and Response Time Table" must be repaired during the construction season. This work should be coordinated with other maintenance activities occurring near the pothole.

Pothole Criteria and Response Time Table

LEVEL OF SERVICE	Level 1A	Level 1B	Level 2	Level 3	Level 4
Type of Roads	All 100 Series and selected high volume highways	All Trunks and selected highways as per AADT limits	All Routes and selected highways as per AADT Limits	All local roads	All gravel roads
AADT Limits	Greater than 7,500	Between 7,500 – 4,000	Between 4,000 – 1,500	Less than 1,500	N/A

Pothole Criteria and Response Time Table

Pothole Criteria	Level 1A	Level 1B	Level 2	Level 3
Description	Potholes which are greater than 0.10 m ² in area (i.e. 0.3 m x 0.3 m) and greater than 100 mm deep.			
Action	Sign immediately and repair within 7 days	Sign immediately and repair within 7 days	Sign within 24 hours and repair within 21 days	Sign within 24 hours and repair within 60 days
Description	Potholes which are greater than 0.10 m ² in area (i.e. 0.3 m x 0.3 m) and between 50 mm and 100 mm deep.			
Action	Sign immediately and repair within 14 days	Sign immediately and repair within 14 days	Sign within 24 hours and repair within 60 days	Sign within 24 hours and repair within 120 days

(Source: Highway Maintenance Standards, Department of Transportation and Infrastructure, Nova Scotia, Canada)

When planning asphalt patching work or setting priority lists, the following types of defects should be considered:

- High concentration of small potholes.
- Segregation/Raveling: Loss of pavement material resulting in surface voids.
- Wheel rutting: Longitudinal depressions in the wheel paths deeper than 20 mm.
- Rippling: A wavy or washboard-like surface across the pavement.
- Cracking: Includes longitudinal, transverse, alligator, and edge cracks.
- Edge loss: Deterioration of the pavement surface near the shoulder.
- Distortions: Any changes in the pavement's original shape.
- Flushing: Polished surface or visible asphalt cement on the pavement.
- Water ponding: Water accumulation on the roadway.
- Repairs around structures such as catch basins, manholes, bridge approaches, and bridge drains..

6.19.3 Measurement and Payment

This work shall be paid based on a unit price ton per day to fully compensate for equipment, materials, labours, efforts and other necessary accessories to complete the work.

Pay items shall be:

6/19/1	Asphalt Patching	Ton per day

6.20 EXTREME WEATHER EVENT DAMAGE MITIGATION

6.20.1 Description

Damage to departmental roads, highways, structures, or other infrastructure resulting from severe weather events and/or natural disasters. The goal is to repair and/or restore these infrastructures to their pre- and post-storm conditions while ensuring public safety during and after the event, whenever feasible.

6.20.2 Work Method

This activity includes all labor, equipment, materials, and contracted services required for cleanup, repair, and public protection following severe weather events or natural disasters. It can only proceed with the Procuring Entity's approval. After a major event, the Engineer will conduct an inspection to assess damage and prioritize the necessary repairs. All available equipment, labor, and materials must be mobilized to minimize the impact of storm damage. The required work must be carried out with the same safety precautions as standard roadwork. Method statements, a priority list, and a checklist of tasks must be submitted. Emergency repairs will be prioritized based on network redundancy and the severity of the damage.

6.20.3 Measurement and Payment

This work shall be paid based on Lump Sum to fully compensate for equipment, materials, labours, efforts and other necessary accessories to complete the work.

Pay items shall be:

6/20/1	Extreme weather events damage mitigation	Lump sum

6.21 WASTE, DEBRIS AND LITTER CLEAN-UP

6.21.1 Description

This activity involves the physical removal of unwanted items from the road surface and right-of-way, followed by their proper disposal. These items include, but are not limited to, roadside rubbish, dead animals, illegal signs, fallen trees, loose brush, and fallen rocks on the road and shoulders, particularly in the Chittagong Hill Tracts. Debris and litter cleanup is essential to prevent damage or injury to the traveling public and maintenance personnel or equipment. Additionally, such debris can harm road structures and cause blockages in drainage systems.

6.21.2 Work Method

All debris must be cleared from the road surface, shoulders, and right-of-way and disposed of in accordance with department policy and current governmental and municipal regulations. Dead animals found on the traveled portion or shoulder of the right-of-way must be properly removed and disposed of.

6.21.3 Measurement and Payment

This work shall be paid based in meters to fully compensate for equipment, materials, labours, efforts and other necessary accessories to complete the work.

Pay items shall be:

6/21/1	Waste, debris and litter cleanup	Meter

6.22 CLEANING DRAINS, CHUTES, AND DRAINAGE STRUCTURES

6.22.1 Description

Drain maintenance involves clearing debris and materials from drains, storm sewers, chutes, as well as pipes and outfall structures. It also includes repairing any structural defects and leaks within the system. The primary goal of this task is to ensure smooth water flow and maintain the system's capacity to handle peak water flows effectively.

6.22.2 Work Method

This system comprises drains, sewers, connections, junction chambers, laterals, manholes, and outfall structures. An "outfall" structure is built at the pipe outlet of a storm sewer system to facilitate the transition between the pipe and a watercourse while preventing erosion at the outlet or in the outfall channel. Storm sewers and outfall structures will be cleaned or repaired as needed to address any potential deficiencies. These deficiencies may include hazards to public safety, flow restrictions, or negative impacts on highway infrastructure.

6.22.3 Measurement and Payment

This work shall be paid based on meter per day to fully compensate for equipment, materials, labours, efforts and other necessary accessories to complete the work.

Pay items shall be:

6/22/1	Cleaning Drains, Chutes, And Drainage Structures	Meter per day

6.23 MAINTENANCE OF CULVERTS

6.23.1 Description

Culvert maintenance involves repairing existing culverts, cleaning both the ends and full lengths, fixing rip rap, excavation, backfilling, and adding surface gravel. It also includes any ditching work within 3 meters of each culvert end. The objective is to ensure efficient water flow and maintain the functional and structural capacity of the culvert to handle peak water flows and meet traffic demands.

6.23.2 Work Method

Existing drainage structures will be maintained to ensure efficient water flow and preserve their functional capacity to handle peak flows. Any culverts that pose or have the potential to create unsafe conditions for the traveling public, adjacent properties, or highway infrastructure will be cleaned as necessary. Immediate removal of obstructions that are causing damage to the culvert, ditch, roadbed, shoulders, or nearby properties, or that pose a safety risk to the public, is required. The contractor is also responsible for ensuring proper driveway installations in line with permit regulations. If conventional methods, such as high-pressure water flushing, fail to clear blocked culverts, specialized techniques may be employed. Additionally, any hand-laid or grouted rip-rap around culvert ends that is damaged or eroded will be repaired, and displaced material replaced as needed.

6.23.3 Measurement and Payment

This work shall be paid based on square meter of culvert area to fully compensate for equipment, materials, labours, efforts and other necessary accessories to complete the work.

Pay items shall be:

6/23/1	Maintenance of Culverts	Square meter

6.24 MAINTENANCE OF HIGHWAY TRAFFIC SIGNS-SIGNALS POSTS, POLES, FRAMES, AND GANTRIES

6.24.1 Description

Sign Maintenance and Repair involves maintaining signs and posts, including tasks such as repairing, repainting, and cleaning existing signs and posts. It also includes replacing signs or posts that are missing or damaged beyond repair. The goal is to maintain the integrity of the signs, ensuring they effectively communicate traffic regulations, warn of road conditions, and provide essential information for route selection to highway users.

6.24.2 Work Method

Signs are devices that may be regulatory, warning, or informational, installed or maintained to provide important information and ensure the safety of the traveling public on highways. Sign Maintenance and Repairs will include, but are not limited to, the following:

- Repair or clean signs that are illegible due to issues such as mud, fading, poor reflectivity, bending, improper orientation, twisting, vandalism, or damage (broken or cracked).
- Replace missing signs or posts, as well as those that are beyond repair, bent, improperly oriented, twisted, broken, or cracked.
- Report all vandalized or stolen signs to the appropriate authority, along with an estimate of the replacement cost.

6.24.3 Measurement and Payment

This work shall be paid based on Lump Sum to fully compensate for equipment, materials, labours, efforts and other necessary accessories to complete the work.

Pay items shall be:

6/24/1	Maintenance of Culverts	Lump Sum



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PREFACE

Chapter 7 (Road Safety) of the RHD Technical Specification, is the first formal initiative by the Roads and Highways Department (RHD) of Bangladesh to develop a dedicated and comprehensive technical specification focused on traffic control devices - including traffic signs, pavement markings, roadside structures, and other road safety-relevant elements. Traditionally, while RHD technical specifications included detailed sections on earthworks, pavements, structures, and foundations, road safety components were typically treated as incidental items, receiving limited attention and lacking sufficient technical detail. This document marks a significant departure from that legacy by establishing a structured, stand-alone specification intended to ensure the systematic and appropriate application of road safety devices and structures across the RHD road network. Specifically, Part I covers static (passive) traffic control devices, which function without active input or real-time control (with a few exceptions). In contrast, Part II will separately address dynamic or intelligent systems that rely on sensing, automation, or active enforcement mechanisms. Moreover, Part II provides a structured framework for the planning, design, and deployment of active, technology-driven systems. These include systems for real-time traffic monitoring, incident detection, speed enforcement, toll collection, axle load control, and centralized command through Traffic Management Centers (TMCs). The development of this specification is a direct response to the increasing need for digital transformation of transport infrastructure in line with global ITS trends and the evolving Bangladesh National ITS Master Plan.

While Part I details the measurement and pay items of traffic control devices, Part II introduces detailed measurement and pay items for each ITS system component. These items are designed to be used either as stand-alone units or as integrated subsystems, depending on the functional requirements of a given project. This modular approach allows for flexibility in procurement, phased implementation, and interoperability across different ITS deployments within the RHD road network.

Road safety remains a pressing issue in Bangladesh, with high rates of crashes and fatalities, particularly involving vulnerable road users such as pedestrians, motorcyclists, and non-motorized transport users. In response to this situation, national-level emphasis has grown in recent years, with increasing alignment toward Safe System principles, evidence-based interventions, and integration of global best practices. Against this backdrop, this specification provides a much-needed foundation for the consistent, technically sound implementation of road safety measures in design, construction, and maintenance.

This edition of the specification has been developed using a reference-based approach to ensure technical rigor and alignment with international best practices. It draws extensively from internationally recognized standards, including those published by the ASTM International, the International Organization for Standardization (ISO), the British Standards Institution (BSI), and the European Norms (EN). Key guidance documents such as the Manual on Uniform Traffic Control Devices (MUTCD), the UK Traffic Signs Manual, the Austroads Guidelines, and relevant Australian Standards (AS) have also been referenced, along with standards issued by the American Association of State Highway and Transportation Officials (AASHTO). To ensure consistency with national regulatory frameworks and engineering practices, relevant local documents, such as the Bangladesh National Building Code (BNBC, 2020), Traffic Signs Manual (BRTA) and RHD Road Safety Engineering Manual (2024), have been incorporated where applicable.

While this version is grounded in global references, local adaptation has been carefully considered to match prevailing construction methods, material availability, and environmental conditions. Testing protocols and quality assurance requirements have been integrated to improve durability, performance, and safety outcomes in the field. This effort also underscores the need for ongoing research and refinement, particularly in domains where international references do not accurately reflect the local traffic mix, behavioral patterns, or operational constraints. Moreover, the specification is expected to stimulate industry readiness by encouraging the development of safety device manufacturing, laboratory testing facilities, and quality control capacities currently underrepresented in the local context.

It is anticipated that this initiative will support RHD's long-term vision for a safer national road network and will serve as a catalyst for institutionalizing road safety across all phases of transport infrastructure planning, design, and execution in Bangladesh.

Section 7: Part I

7.1. TRAFFIC SIGNS

7.1.1. General

Traffic signs are standardized visual devices used to communicate essential regulatory, warning, and guidance information to road users, ensuring safe, efficient, and predictable use of the road network. As a fundamental element of the Safe System approach and the concept of self-explanatory roads (SER), their effectiveness depends on uniformity, conspicuity, legibility, and relevance. Signs must be clearly visible, easily understood at appropriate speeds, and consistently applied across the RHD network to minimize cognitive load and support safe decision-making. Bilingual inscriptions, standardized symbols, and proper placement are essential to accommodate diverse road user groups and promote road user education.

For all categories of roads managed by the Roads and Highways Department (RHD), including Zilla Roads, Regional Highways, National Highways, and Expressways, the shape, color, configuration, dimensions, and placement of traffic signs shall conform to the standards outlined in RHD Road Safety Engineering Manual 2024 or as specified in approved engineering drawings.

Where the competent authority advises to make the meaning of a sign or symbol more explicit, or in the case of regulatory signs, limit their application to certain categories of road users or for specific time periods, then an inscription shall be placed below the traffic sign in a rectangular supplementary plate of suitable size. The supplementary plate shall be retro-reflective with a color code provided in the Road Safety Engineering Manual of Roads and Highways Department. Numerals and text messages shall be in Bengali and English languages as necessary.

All traffic signs and their support structures shall be designed to withstand environmental conditions, including wind loads and seismic loads as per BNBC 2020. The design of signposts shall prioritize safety through frangibility, minimizing impact severity in the event of a collision. The construction of overhead sign support structures, such as gantries and cantilever arms, shall adhere to sound engineering principles, ensuring adequate stiffness, stability, resistance to deflections, vibrations, buckling, and durability against environmental degradation.

For fabrication, sign plates, poles, frames, and stiffeners, fixtures and fittings shall be made of corrosion-resistant materials, such as high-quality aluminum, or, wherever applicable, pre-steel sections shall be protected by galvanization or a paint system followed by appropriate surface preparation, ensuring compliance with international standards for durability. The selection of retro-reflective sheeting shall be based on road classification and visibility requirements, following the performance criteria outlined in international standards or the RHD Road Safety Engineering Manual 2024.

7.1.2. Mounting Configuration

Traffic signs may be categorized based on their mounting configuration into post-mounted and overhead-mounted types. Post-mounted signs are installed at the roadside using either single or double vertical posts and are commonly used for regulatory, warning, and smaller informatory signs. Single-post mounts are typically used for standard-sized signs, while double-post mounts provide additional support for larger or wider signs. In contrast, overhead-mounted signs are installed above the roadway to enhance visibility, particularly on high-speed, multilane, or complex road segments. These include gantry-mounted signs, which span across the carriageway and are supported by vertical columns on both sides, and cantilever-mounted signs, which project over the roadway from one side using a horizontal arm connected to a vertical post. The selection of mounting type depends on road classification, available space, visibility requirements, and structural considerations, as detailed in the RHD Road Safety Engineering Manual 2024.

7.1.2. Materials

7.1.2.1. Sign Posts

Signposts should be designed to be frangible in the event of impact by an errant vehicle (i.e., posts that are designed to fracture, break away, give way, or bend), such that the damage to a colliding vehicle and risk of injury to vehicle occupants upon impact is minimized. Small signs are usually supported by posts that deform in a way that causes minimum damage to cars, whereas larger posts and supports (for larger signs) may be provided with mechanisms that are designed to yield in a controlled manner upon impact.

To ensure post-mounted signs meet frangibility requirements and minimize impact severity during collisions, the maximum allowable design moment for small steel posts shall conform to the limits shown in Table 7.1-1, based on the operating speed of the road.

Table 7.1-1: Steel posts considered frangible

Operating speed (km/hr)	Maximum moment (kNm)
<60	7.90

60 to 80	3.95
>80	3.01

Source: Department of Planning, Transport and Infrastructure. (2016). Guide to Traffic Engineering Practice. Adelaide, South Australia

Table 7.1-2: A guiding example for small signposts that can be considered frangible is as follows:

Circular steel posts	
Speed zone (km/hr)	Diameter (mm) x wall thickness (mm)
≤ 80	80 x 3.3
≤ 70	90 x 3.3
≤ 60	80 x 5.0 or 100 x 3.5
≤ 50	125 x 3.5
Circular aluminum posts	
≤ 80	100 x 4.6

Note: All circular post sizes are shown as nominal bore (inside dimension)

Source: Department of Planning, Transport and Infrastructure. (2016). Guide to Traffic Engineering Practice. Adelaide, South Australia

If the post requires a higher design moment, as indicated in Table 7.1-1, a frangible support should be utilized. Frangible supports are engineered to yield or collapse upon impact, thereby minimizing the risk of severe injuries to vehicle occupants compared to rigid, non-yielding supports.

Types of poles with frangible supports include:

- Slip-base poles: These are designed to detach at the base upon impact, allowing the vehicle to pass underneath, thereby reducing the likelihood of serious injury to occupants.
- Impact-absorbing poles: These deformable poles collapse over the vehicle upon collision, slowing it down in a controlled manner. Unlike slip-base poles, they remain anchored to the ground after impact.

Impact-absorbing poles are generally preferred over slip-base designs in environments with dense development, pedestrian movement, on-street parking, or lower traffic speeds. Relevant design guidelines for poles with frangible supports can be found in the RHD Road Safety Engineering Manual 2024.

7.1.2.2. Sign Plates and Supplementary Plates

Sign plates and supplementary plates, which serve as the substrate for retro-reflective sheeting in traffic signs, shall be fabricated from high-quality aluminum sheets, or mild steel coated with a protective zinc layer, or made of pre-galvanized steel (Galvanized Plain Sheet)/ continuously hot-dip coated steel flat products, ensuring durability and long-term performance under outdoor environmental conditions.

Aluminum Sheets shall conform to ASTM B209, BS 1470, or an equivalent internationally recognized standard approved by the Engineer.

Mild Steel Sheets shall conform to ASTM A6/A6M (*Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*) and ASTM A1011/A1011M (*Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy*) or an equivalent international standard. The surface shall be protected by:

- Post hot-dip galvanization in accordance with ASTM A123/A123M, or
- Continuous hot-dip coating as per ASTM A653/A653M, which covers pre-galvanized plain sheets (GPS)

The substrate material shall provide a smooth and dimensionally stable surface for the application of retro-reflective sheeting and must be resistant to UV radiation, moisture, atmospheric pollutants, and other environmental degradations.

The minimum thickness requirements for aluminum and galvanized steel plates, depending on application size, are specified in Table 7.1-3. These thicknesses are intended to ensure structural rigidity and resistance to wind loads under operational conditions. However, all sign plates shall be capable of withstanding a wind pressure of not less than 150 kg/m² without structural failure or deformation.

Table 7.1-3: Minimum thickness requirements of sign and supplementary plates.

Material Type	Application	Minimum Thickness
Galvanized Steel	Small Signs	1.5 mm
	Large Signs ($\geq 1.2 \text{ m}^2$)	2.0 mm
Aluminum	Small Signs	2.0 mm
	Large Signs ($\geq 1.2 \text{ m}^2$)	3.0 mm

The protective zinc coating shall be uniform, free from cracks, blisters, and uncoated areas, and shall ensure full protection against rust and corrosion. Chromate passivation (using hexavalent or trivalent chromium solution) or a suitable primer treatment shall be applied to enhance the adhesion of retro-reflective sheeting. Edges, holes, and other fabricated areas shall be properly treated using zinc-rich paint or galvanizing compounds to prevent corrosion.

The final shapes and dimensions of the sign plates and supplementary panels shall strictly adhere to the Engineering Drawings and the RHD Road Safety Engineering Manual 2024.

7.1.2.3. Frames and Stiffeners

Traffic sign plates shall be reinforced using frames or stiffeners to ensure durability, stability, and resistance to environmental conditions. The stiffeners and frames must be structurally compatible with the sign plate material to prevent corrosion and ensure long-term performance.

Material Selection & Corrosion Resistance

- For Galvanized Steel Sign Plates: Stiffeners and frames shall be made of mild steel with hot-dip galvanization (as per ASTM A123/A123M) to prevent corrosion.
- For Aluminum Sign Plates: Frames and stiffeners shall be made of aluminum (as per ASTM B209) or stainless steel (SS 304 or SS 316) to prevent galvanic corrosion.
- Mixed-Material Use: If different materials are used for the frame and sign plate, a non-conductive insulating layer or gasket shall be applied to prevent bimetallic (galvanic) corrosion. Direct welding between aluminum and steel must be avoided.

Stiffening Requirements

- Sheet metal sign plates exceeding 500 mm in any dimension shall be reinforced with stiffening members or frames attached to the back of the sign.
- Stiffening elements shall be integral to the sign plate (such as ribs or flanges) or attached externally.
- All stiffeners and frames shall be designed to resist deformation and withstand wind loads of at least 150 kg/m².

Frame Design and Fabrication:

Frames may consist of flanged edges, welded ribs, or separate structural members securely attached to the sign plate. All frame components, whether made of steel or aluminum, shall have a minimum thickness of 3 mm to provide sufficient rigidity under operational loads. Frames shall be applied uniformly along all edges of the sign plate to enhance structural strength, ensure consistency, and facilitate proper alignment during installation.

7.1.2.4. Fixtures and Fittings

The fixing method for sign plates, frames, and brackets shall allow easy removal for maintenance or replacement while ensuring the sign remains securely attached to withstand the specified loads. Signs mounted on single posts shall be fixed with welded or mechanical fasteners to prevent rotation under external forces. Clips and brackets shall be designed to hold the sign firmly on the post without imposing bending stress on the sign plate.

When joining different metals, precautions shall be taken to prevent:

- Galvanic corrosion caused by electrolytic action.
- Differential thermal expansion leading to joint failure.
- Formation of intermetallic compounds that weaken the structure.

The following principles for fixing and fitting shall be considered:

- Frame components shall be welded, bolted, or riveted using stainless steel (SS 304 or SS 316) fasteners for corrosion resistance.
- Steel welding shall conform to AWS D1.1/D1.1M - Structural Welding Code - Steel.
- Aluminum welding shall comply with AWS D1.2/D1.2M - Structural Welding Code - Aluminum.
- Direct welding between aluminum and steel shall be avoided due to weak joints and corrosion risks.
- Where welding is not suitable, mechanical fasteners with non-conductive separators (e.g., nylon washers, rubber gaskets) shall be used to connect aluminum and steel.
- For mechanical fastening (bolts, screws, rivets), protective measures such as paint, lacquer, or non-conductive washers shall be used to eliminate metal-to-metal contact, preventing corrosion.
- Where welding is not feasible, alternative bonding methods such as adhesive bonding, bimetallic transition inserts, or a combination of riveting/bolting and adhesives shall be considered for connections between steel frames and aluminum plates.

While using mechanical fasteners,

- Screws and bolts shall be a minimum of 8 mm (5/16 inch) in diameter and of adequate length to ensure secure fastening without excessive projection.
- Screws critical to the integrity of the assembly shall have at least four full threads protruding when fully tightened and shall be secured with a locknut.
- Hollow rivets used for fixing sign plates to frames shall have their holes sealed to prevent light from passing through.
- Screw, bolt, or rivet heads visible on the sign face shall be unobtrusive and color-matched to blend with the sign's background.

Brackets used for sign installation shall be fabricated from sheet or extruded aluminum alloy or steel sections, with materials selected to ensure compatibility with the sign plate and prevent galvanic corrosion. All brackets shall be structurally sound and designed to withstand environmental and operational stresses. The minimum thickness shall be 3 mm for brackets, and 2 mm for associated clips and strips, to ensure durability, stability, and long-term performance.

For post caps and weather protection, all hollow-section posts shall be fitted with rain-shedding caps to prevent water ingress and internal corrosion. These caps shall be securely fastened to the posts to ensure they remain in place under wind loads, vibration, and other environmental conditions.

All materials, components, and fastening arrangements shall be submitted by the contractor for prior approval by the Engineer before fabrication and installation.

7.1.2.5. Preservatives, Paints, and Finishes for Posts and Fittings

All exposed steel surfaces shall receive appropriate protective treatments to prevent corrosion and ensure durability. The finishing options shall include hot-dip galvanization (zinc coating) or high-performance paint systems consisting of an anti-corrosive primer and topcoat.

Hot-dip galvanization (zinc coating):

For enhanced corrosion resistance, steel components (poles, frames, stiffeners, etc.) shall be zinc-coated using methods like hot-dip galvanizing. The coatings shall comply with ASTM A123 for large structural elements (for both unfabricated products and fabricated products, for example, assembled steel products, structural steel fabrications, large tubes already bent or welded before galvanizing, and wire work fabricated from uncoated steel wire) and ASTM A153 for smaller hardware and fasteners (hardware items that are to be centrifuged or otherwise handled to remove excess zinc such as bolts and similar threaded fasteners, castings and rolled, pressed and forged items). Zinc-coated parts generally do not require additional painting unless specified in the Engineering drawings. Where painting is necessary, a high zinc oxide content primer conforming to ISO 12944-5:2018 or an epoxy-based coating with a UV-resistant topcoat compliant with ASTM D520 (zinc-rich primers) shall be used to ensure long-term corrosion protection and weather resistance.

General requirements

The zinc-coated articles shall be free from uncoated areas, blisters, flux deposits, dross inclusions, and other types of projections that would interfere with the intended use of the articles, or other defects not consistent with good galvanizing practice. Similar to large structural elements, testing shall be done for average thickness of coating, adherence, and embrittlement.

Before galvanization, the specification, grade, or designation and type and degree of surface contamination of the iron or steel in articles to be galvanized shall be supplied by the contractor to the hot-dip galvanizer prior to galvanizing.

Some types of castings have been known to show potential problems with predisposition to being embrittled during the normal thermal cycle of hot-dip galvanizing. It is the responsibility of the contractor to heat treat or otherwise allow for the possibility of such embrittling phenomena.

The zinc used in the galvanizing bath shall conform to either Specification B6 or Specification B960, or both. If a zinc alloy is used as the primary feed to the galvanizing bath, then the base material used to make that alloy shall conform to Specification B6, or Specification B960, or both. The molten metal in the working volume of the galvanizing bath shall contain not less than an average value of 98.0 % zinc by weight.

Surfaces that remain uncoated after galvanizing shall be renovated in accordance with the methods in Practice A780 unless directed by the Engineer to leave the uncoated areas untreated for subsequent renovation by the Contractor. Each area subject to renovation shall be 25 mm or less in its narrowest dimension. The total area subject to renovation on each article shall be no more than 1/2 of 1 % of the accessible surface area to be coated on that article, or 256 cm² per metric ton of piece weight, whichever is less. The thickness of renovation shall be that required by the thickness grade for the appropriate material category and thickness range in Table 7.1-4. When areas requiring renovation exceed the criteria previously provided or are inaccessible for repair, the coating shall be rejected.

Lumps, projections, globules, or heavy deposits of zinc that will interfere with the intended use of the material shall not be permitted. Plain holes of 12.5-mm diameter or more shall be clean and reasonably free from excess zinc.

Articles shall be free of black surfaces where “black” denotes the condition of not galvanized or otherwise coated. It does not refer to the color or condition of the surface, or to a surface deposit or contamination.

Surface preparation

Proper surface preparation requirements shall be complied with for a high-quality, uniform, and durable galvanized coating.

ASTM A385 (Practice for Providing High-Quality Zinc Coatings) shall be followed as a guideline for steel surface preparation before zinc coating. ASTM A385 outlines best practices for surface preparation to achieve high-quality hot-dip galvanized coatings. It emphasizes the removal of contaminants, including grease, oil, paint, rust, and welding slag, which can hinder zinc adhesion. Steel chemistry, particularly silicon and phosphorus content, must be controlled to prevent excessively thick or brittle coatings. Ensuring uniform surface conditions minimizes coating irregularities, while proper venting and drainage design prevent defects by allowing complete zinc coverage.

In addition, steel surfaces before zinc coating shall be considered for degreasing and cleaning to remove oils, grease, and contaminants using solvent cleaning (ASTM D6386), alkaline cleaning (caustic soda or detergents), or emulsion cleaning. Mill scale and rust shall be removed through acid pickling, typically using sulfuric acid (10-15%) at ~60°C or hydrochloric acid (5-15%) at room temperature. For heavy scale or large surfaces, mechanical cleaning methods such as grit blasting

(SSPC-SP10/NACE No.2) or shot blasting are typically used. Before dipping in molten zinc, fluxing is applied to prevent oxidation; this can be done through wet fluxing, where steel is pre-dipped in zinc ammonium chloride, or dry fluxing, where a flux layer is maintained over the zinc bath.

A typical process of hot-dip galvanizing may include the following steps:

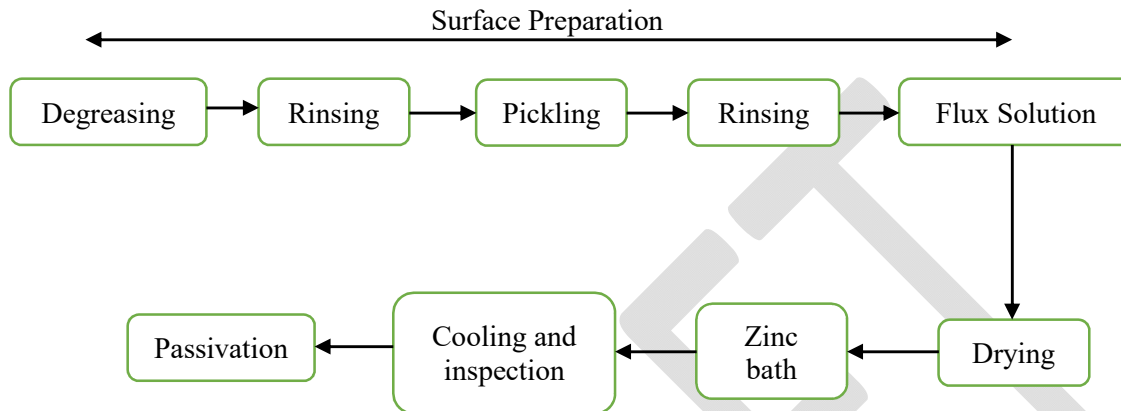


Figure 7.1-1: Typical hot-dip galvanization process.

Thickness requirement

The minimum average coating thickness for hot-dip galvanized steel products, as per ASTM A123/A123M, varies based on the material category and steel thickness. The required coating thickness increases with the thickness of the steel and typically ranges from 35 μm to 100 μm . For structural shapes, plates, bars, pipes, and other steel products, the minimum coating thickness shall conform to the values specified in Table 7.1-4 (applicable unit is micrometers) of the standard. If additional coating thickness is required, it must be mutually agreed upon between the Contractor and the Engineer.

Table 7.1-4: Minimum average coating thickness grade of large structural elements by material category [ASTM A123/A123M].

Material Category	Steel thickness range (mm)					
	<1.6	1.6~3.2	3.2~4.8	4.8~6.4	6.4~16	>16
Structural shapes (μm)	45	65	75	75	100	100

Strips and Bar (μm)	45	65	75	75	75	100
Plate (μm)	45	65	75	75	75	100
Pipe and Tubing (μm)	45	45	75	75	75	75
Wire (μm)	35	50	60	65	80	80
Reinforcing Bar (μm)	-	-	-	-	100	100

The minimum average coating thickness for hot-dip galvanized fasteners and small hardware, as per ASTM A153/A153M, varies based on the size and classification of the material. The required average coating thickness typically ranges from 43 μm to 86 μm, depending on the class of material. Fasteners, rivets, nails, and washers shall conform to the specified minimum coating thickness values in Table 7.1-5 shown below. If a higher coating thickness is required, it must be mutually agreed upon between the Contractor and the Engineer.

Table 7.1-5: Minimum average coating thickness grade of small hardware and fasteners by material category [ASTM A153/A153M].

Class of Material	Minimum coating thickness (micrometers)	
	Average	Any individual
<i>Class A</i> —Castings—Malleable Iron, Steel <i>Class B</i> —Rolled, pressed, and forged articles (Except those which would be included under Classes C and D)	86	79
B-1—5/8 in. [15.88 mm] and over in thickness and over 15 in. [381 mm] in length	86	79
B-2—under 5/8 in. [15.88 mm] in thickness and over 15 in. [381 mm] in length	66	53
B-3—any thickness and 15 in. [381 mm] and under in length	56	48
<i>Class C</i> —Fasteners over 3/8 in. [9.52 mm] in diameter and similar articles. Washers 3/16 in. and greater [4.76 mm and greater] in thickness	53	43
<i>Class D</i> —Fasteners 3/8 in. [9.52 mm] and under in diameter, rivets, nails, and similar articles. Washers under 3/16 in. [4.76 mm] in thickness	43	36

Testing Requirements

- Thickness of Coating Test: The thickness of the coating shall be determined by magnetic thickness gage measurements in accordance with ASTM E376.
- Adhesion Test: Determine adhesion of the zinc coating to the surface of the base metal by cutting or prying with the point of a stout knife, applied with considerable pressure in a manner tending to remove a portion of the coating. The adhesion shall be considered inadequate if the coating flakes off in the form of a layer of the coating so as to expose the base metal in advance of the knife point.
- Embrittlement: Test for embrittlement shall be made in accordance with ASTM A143/A143M. These tests shall not be required unless strong evidence of embrittlement is present.

Sign faces shall remain unpainted to maintain visibility and effectiveness.

Paint systems:

The protective paint system for steel structures used in traffic sign installations shall conform to ISO 12944-2:2017, ensuring corrosion resistance suitable for Bangladesh's environmental conditions. Based on environmental exposure classification, C4 (high corrosivity) or C5 (very high corrosivity) categories shall apply, considering industrial pollution, coastal humidity, and high rainfall. The paint system must provide at least medium-term durability (7~15 years) as specified in ISO 12944-1:2017 to minimize maintenance costs and ensure structural integrity.

Surface Preparation

Surface preparation shall follow ISO 12944-4:2018, ensuring optimal adhesion and performance of protective coatings. The following steps shall be maintained:

1. Cleaning and Contaminant Removal

Before any mechanical or chemical surface preparation, all steel surfaces must be thoroughly cleaned to eliminate oil, grease, dirt, salts, and other contaminants that could interfere with paint adhesion. Cleaning shall be performed using one or more methods as outlined in ISO 12944-4:2018, including solvent cleaning (ISO 8502-3) for the removal of organic contaminants such as oils and greases, alkaline or detergent cleaning when solvent cleaning is insufficient, and freshwater washing to remove chlorides and sulfates, particularly in coastal areas and industrial zones where salt contamination is common. After cleaning, surfaces must be completely dry before further treatment to prevent flash rusting and ensure optimal adhesion of subsequent coatings.

In coastal areas, the best available clean water shall be used for washing. Potable freshwater is preferable; however, where it is not available, other water sources may be used if they are reasonably free from visible contaminants and excessive salinity, and the washed surface is free of visible salt

deposits. As a guideline, chloride levels should preferably be below 250 mg/L, in accordance with the *World Health Organization (WHO) Guidelines for Drinking-water Quality*, which note that concentrations above this can impart a salty taste and indicate higher salinity. If salt residue remains, the surface shall be rewashed until adequately clean and must be fully dried before coating.

2. Abrasive Blast Cleaning

To achieve a high-performance protective coating, abrasive blast cleaning shall be carried out to a minimum of Sa 2½ grade¹ as per ISO 8501-1, ensuring the removal of mill scale, rust, and other foreign matter. The surface profile shall be prepared according to ISO 8503-1, providing an adequate roughness that promotes strong mechanical bonding of the coating system. The abrasives used shall be clean, dry, and free from contaminants. After blasting, all residues and dust shall be removed in accordance with ISO 8502-3, ensuring that the surface is free of deposits that may interfere with adhesion.

3. Treatment of Hot-Dip Galvanized Steel

For hot-dip galvanized steel components, additional surface preparation is required to improve paint adhesion. Sweep blasting (ISO 12944-4:2018, Section 6.4) shall be performed using non-metallic abrasives at low pressure (~2.5 bar) to create a slightly roughened profile while preserving the integrity of the zinc layer. Alternatively, chemical etching using mild phosphoric acid-based solutions may be applied where sweep blasting is not feasible. Degreasing and rinsing must be performed to remove any residues from galvanization, such as white rust, to ensure a clean, adhesion-ready surface before applying the coating system.

4. Edge Preparation and Weld Treatment

Sharp edges, burrs, and welding defects must be ground and smoothed before painting to prevent coating failures. According to ISO 12944-4 (Section 6.3), all edges shall be rounded to a minimum radius of 2 mm to ensure uniform coating thickness and prevent early coating breakdown. Additionally, weld seams and heat-affected zones (HAZ) must be ground smooth to eliminate surface irregularities that could lead to weak adhesion or premature failure of the protective coating. Proper edge preparation is essential for ensuring consistent coverage, durability, and long-term corrosion resistance of the painted steel structures.

Paint coating requirements

¹ Sa 2½ is a surface preparation grade defined in ISO 8501-1:2007 (“Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness”). Sa = *Sandblasting* (or more generally, *abrasive blast cleaning*). 2½ = *Very thorough blast-cleaning* level, just short of white metal finish.

Sa grades: Sa 1 – Light blast cleaning, Sa 2 – Thorough blast cleaning, Sa 2½ – Very thorough blast cleaning (near-white metal), Sa 3 – Blast cleaning to visually clean steel (white metal).

The paint coating requirements for steel and aluminum alloy components used in road safety structures such as poles, portals, and gantries for traffic sign installations shall be based on ISO 12944-2:2017; ISO 12944-4:2018, and ISO 12944-5:2019, ensuring corrosion protection, durability, and adherence to international standards. ISO 12944-5:2019 denotes 5 corrosive categories as C1 (very low), C2 (low), C3 (medium), C4 (high), and C5 (very high). Further, ISO 12944-5:2019 denotes the durability of the paint system as low (L) up to 7 years, medium (M) for 7 to 15 years, and high (H) for 15 to 25 years. The classification of corrosivity categories (C3 to C5) and durability level (medium) is considered to determine appropriate coating systems for the environmental conditions in Bangladesh, including rural (C3), urban & industrial (C4), and coastal (C5) exposures.

The following coating systems are recommended in ISO 12944-5:2019:

Alkyd (AK): A single-pack air-drying coating that cures by solvent evaporation and reaction with atmospheric oxygen. It is mainly used for low-corrosivity environments (C2, C3) and provides good aesthetics but moderate durability.

Epoxy (EP): A two-pack chemically curing coating that provides high corrosion resistance and mechanical strength. It is commonly used as a primer or intermediate coat in C3 to C5 environments, but requires a UV-resistant topcoat to prevent chalking.

Acrylic (AY): A single-pack coating available in water-borne and solvent-borne forms. It dries by solvent evaporation and offers good weather resistance but lower chemical resistance. It is used in moderate corrosion environments (C2, C3, C4).

Polyurethane (PUR): Available as single-pack or two-pack systems, polyurethane coatings cure by reaction with moisture or a chemical hardener. They provide excellent UV resistance and are used as topcoats in high-corrosivity areas (C3 to C5).

Ethyl Silicate (ESI): A two-pack coating primarily used as a zinc-rich primer for corrosion protection. It reacts with moisture from the air to form a durable film and is commonly used in harsh environments (C4, C5, immersion conditions).

Table 7.1-6 shows the minimum required number of coats and nominal dry film thickness of the paint system depending on durability and corrosive category on abrasive blasted steel surface

A multi-layer coating system shall be applied for the Bangladesh atmosphere as per ISO 12944-5:2019 for environmental exposure classification, C3 (low), C4 (high corrosivity), and C5 (very high corrosivity) categories as per Tables 7.1-6, 7.1-7, and 7.1-8, respectively.

Table 7.1-6: Paint systems for low corrosive category C3 [ISO 12944-5:2019].

System No.	Priming coat			Subsequent coat(s)	Paint system			Durability			
	Binder type	Type of primer	No. of coats		Binder type	Total no. of coats	NDF T in μm	l	m	h	vh
C3.01	AK, AY	Misc.	1	80 to 100	AK, AY	1 to 2	100	X			
C3.02	AK, AY	Misc.	1	60 to 160	AK, AY	1 to 2	160	X	X		
C3.03	AK, AY	Misc.	1	60 to 80	AK, AY	2 to 3	200	X	X	X	
C3.04	AK, AY	Misc.	1	60 to 80	AK, AY	2 to 4	260	X	X	X	X
C3.05	EP, PUR, ESI	Misc.	1	80 to 120	EP, PUR, AY	1 to 2	120	X	X		
C3.06	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2	180	X	X	X	
C3.07	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2 to 3	240	X	X	X	X
C3.08	EP, PUR, ESI	Zn (R)	1	60	—	1	60	X	X		
C3.09	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160	X	X	X	
C3.10	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2 to 3	200	X	X	X	X

Note: NDFT: Nominal dry film thickness; AK: Alkyd; Ep: Epoxy; AY: Acrylic; PUR: Polyurethane; Zn(R): Zinc-rich primer; ESI: Ethyl Silicate; l: low; m: medium; h: high; vh: very high.

Table 7.1-7: Paint systems for high corrosive category C4 [ISO 12944-5:2019].

System No.	Priming coat			Subsequent coat(s)	Paint system			Durability			
	Binder type	Type of primer	No. of coats		Binder type	Total no. of coats	NDFT in μm	l	m	h	vh
C4.01	AK, AY	Misc.	1	60 to 160	AK, AY	1 to 2	160	X			
C4.02	AK, AY	Misc.	1	60 to 80	AK, AY	2 to 3	200	X	X		
C4.03	AK, AY	Misc.	1	60 to 80	AK, AY	2 to 4	260	X	X	X	

C4.04	EP, PUR, ESI	Misc.	1	80 to 120	EP, PUR, AY	1 to 2	120	X	X		
C4.05	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2	180	X	X		
C4.06	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2 to 3	240	X	X	X	
C4.07	EP, PUR, ESI	Misc.	1	80 to 240	EP, PUR, AY	2 to 4	300	X	X	X	X
C4.08	EP, PUR, ESI	Zn (R)	1	60	—	1	60	X			
C4.09	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160	X	X		
C4.10	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2 to 3	200	X	X	X	
C4.11	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	3 to 4	260	X	X	X	X

Note: NDFT: Nominal dry film thickness; AK: Alkyd; Ep: Epoxy; AY: Acrylic; PUR: Polyurethane; Zn(R): Zinc-rich primer; ESI: Ethyl Silicate; l: low; m: medium; h: high; vh: very high.

Table 7.1-8: Paint systems for very high corrosive category C5[ISO 12944-5:2019].

System No.	Priming coat			Subsequent coat(s)	Paint system			Durability			
	Binder type	Type of primer	No. of coats		Binder type	Total no. of coats	NDFT in μm	l	m	h	vh
C5.01	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2	180	X			
C5.02	EP, PUR, ESI	Misc.	1	80 to 160	EP, PUR, AY	2 to 3	240	X	X		
C5.03	EP, PUR, ESI	Misc.	1	80 to 240	EP, PUR, AY	2 to 4	300	X	X	X	
C5.04	EP, PUR, ESI	Misc.	1	80 to 200	EP, PUR, AY	3 to 4	360	X	X	X	X
C5.05	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2	160	X	X		

C5.06	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	2 to 3	200	X	X		
C5.07	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	3 to 4	260	X	X	X	
C5.08	EP, PUR, ESI	Zn (R)	1	60 to 80	EP, PUR, AY	3 to 4	320	X	X	X	X

Note: NDFT: Nominal dry film thickness; AK: Alkyd; Ep: Epoxy; AY: Acrylic; PUR: Polyurethane; Zn(R): Zinc-rich primer; ESI: Ethyl Silicate; l: low; m: medium; h: high; vh: very high.

Application Guidelines

- All coating processes shall be applied as per the manufacturer's specifications, ensuring compliance with ISO 12944-5:2019.
- The application shall be carried out in controlled conditions, ensuring the substrate is dry, free from dust, and within recommended temperature and humidity limits.
- The final coating shall be inspected for adhesion, uniformity, and coverage, ensuring compliance with ISO 12944-6 (Performance Testing).

Others:

If paint is required on hot-dip galvanized steel components, Table 7.1-9 shall be followed, which shows the minimum number of coats and minimum nominal dry film thickness of the paint system depending on durability and corrosivity category on hot-dip galvanized steel:

Table 7.1-9: Minimum number of coats and nominal dry film thickness of the paint system depending on durability and corrosive category on hot dip galvanized surface [ISO 12944-5:2019].

Durability (Corrosive Category)		Low (l)		Medium (m)		High (h)		Very high (vh)	
Binder base of primer		EP, PUR	AY	EP, PUR	AY	EP, PUR	AY	EP, PUR	AY
Binder base of subsequent coats		EP, PUR, AY	AY	EP, PUR, AY	AY	EP, PUR, AY	AY	EP, PUR, AY	AY
C2	MNOC	a		a		1	1	1	2
	NDFT					80	80	120	160
C3	MNOC	a		1	1	2	2	2	2
	NDFT			80	80	120	160	160	200
C4	MNOC	1	1	1	2		2	2	—
	NDFT	80	80	120	160	160	200	200	—
C5	MNOC	1	1	2	2	2	—	2	—
	NDFT	120	120	160	200	200	—	240	—

Note: NDFT: Nominal dry film thickness; MNOC: Minimum number of coats; AK: Alkyd; Ep: Epoxy; AY: Acrylic; PUR: Polyurethane; Zn(R): Zinc-rich primer; ESI: Ethyl Silicate; l: low; m: medium; h: high; vh: very high.

For aluminum alloy parts requiring painting, a primer pigmented with chromates or chromes (pigments contain chromium compounds, typically hexavalent chromium (Cr^{6+}) or trivalent chromium (Cr^{3+}), which enhance corrosion resistance, adhesion, and durability of the coating system excluding lead chromes) shall be applied, conforming to “MIL-DTL-5541 (Chemical Conversion Coatings on Aluminum) or MIL-PRF-23377 (Epoxy Primer for Aluminum Alloys)”.

- MIL-DTL-5541 covers chromate-based conversion coatings, which improve adhesion and corrosion resistance for aluminum (U.S. Department of Defense; 2006).
- MIL-PRF-23377 is widely used for chromated epoxy primers on aluminum substrates, ensuring proper adhesion and long-term protection (U.S. Department of Defense; 2013).

7.1.2.6. Traffic Signs having Retro-reflective Sheeting

General requirements

The sheeting used on steel or aluminum substrate to delineate legends for traffic signs shall consist of high-quality retro-reflective materials from known and reputed brands having a smooth outer surface that has the property of retro-reflection over its entire surface. It shall be weather-resistant and show colorfastness. It shall be new and unused and shall show no evidence of cracking, scaling, pitting, blistering, edge lifting, or curling, and shall have negligible shrinkage or expansion.

Retro-reflection Requirements

There are numerous materials available for retro-reflection, as well as various methods for illuminating signs and object markers. New materials and processes are constantly being developed. New materials and methods can be utilized as long as the signs and object markers fulfil the color standards for both day and night. The requirements for classes, types, coefficient of retro-reflection, applicability, warranty periods, with minimum retention of coefficient of retro-reflection of retro-reflective sheeting applicable on different types of highways shall be followed from the RHD Road Safety Engineering Manual 2024.

Among the acceptable types as specified in ASTM D 4956-09, available types among different types of retro-reflective sheeting in Bangladesh are limited to type I, II from Class A, type III, IV from Class B, and type IX, XI from Class C. However, based on recent technological advancements and the generalization need, the following three types shall be applied on most of the road networks of Roads and Highways Department (RHD):

- Type II: A retro-reflective sheeting referred to as “super engineer grade” that is typically an enclosed lens glass-bead sheeting.
- Type-IV: A retro-reflective sheeting referred to as “high-intensity” that is typically an unmetallized micro prismatic retro-reflective element material.
- Type- XI: A retro-reflective sheeting typically manufactured as an unmetallized cube corner micro prismatic retro-reflective element material.

The acceptable minimum coefficients of retro-reflection for these sheeting types as per ASTM D 4956-09 are given in Tables 7.1-10, 7.1-11, and 7.1-12.

Table 7.1-10: Acceptable minimum coefficient of retro-reflection for Type II sheeting ($\text{cd.m}^{-2} \cdot \text{lx}^{-1}$)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown
0.2°	−4°	140	100	60	30	30	10	5.0
0.2°	+ 30°	60	36	22	10	12	4.0	2.0
0.5°	− 4°	50	33	20	9.0	10	3.0	2.0
0.5°	+ 30°	28	20	12	6.0	6.0	2.0	1.0

Table 7.1-11: Acceptable minimum coefficient of retro-reflection for Type IV sheeting ($\text{cd.m}^{-2} \cdot \text{lx}^{-1}$)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow-Green ^B	Fluorescent Yellow	Fluorescent Orange
0.1° ^A	−4°	500	380	200	70	90	42	25	400	300	150
0.1° ^A	+ 30°	240	175	94	32	42	20	12	185	140	70
0.2°	− 4°	360	270	145	50	65	30	18	290	220	105
0.2°	+ 30°	170	135	68	25	30	14	8.5	135	100	50
0.5°	−4°	150	110	60	21	27	13	7.5	120	90	45
0.5°	+ 30°	72	54	28	10	13	6	3.5	55	40	22

A = Values for 0.1° observation angles are supplementary requirements that shall apply only when specified by the contractor in the contract or order.

B = The luminance factors shown for fluorescent colors consist of the sum of a reflectance luminance factor and a fluorescence luminance factor.

Table 7.1-12: Acceptable minimum coefficient of retro-reflection for Type XI sheeting ($\text{cd.m}^{-2} \cdot \text{lx}^{-1}$)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow-Green ^B	Fluorescent Yellow	Fluorescent Orange
0.1° ^A	−4°	830	620	290	83	125	37	25	660	500	250
0.1° ^A	+ 30°	325	245	115	33	50	15	10	260	200	100
0.2°	− 4°	580	435	200	58	87	26	17	460	350	175
0.2°	+ 30°	220	165	77	22	33	10	7.0	180	130	66
0.5°	−4°	420	315	150	42	63	19	13	340	250	125
0.5°	+ 30°	150	110	53	15	23	7.0	5.0	120	90	45
1.0°	−4°	120	90	42	12	18	5.0	4.0	96	72	36
1.0°	+ 30°	45	34	16	5.0	7.0	2.0	1.0	36	27	14

A = Values for 0.1° observation angles are supplementary requirements that shall apply only when specified by the contractor in the contract or order.

B = The luminance factors shown for fluorescent colors consist of the sum of a reflectance luminance factor and a fluorescence luminance factor. The luminance factor may be determined using a good approximation to Illuminant D65, requiring an instrument with an appropriately filtered light source, or by using a bi-spectral photometer conforming to Test Method ASTM-E2301.

A "higher" type/class of sheeting need not necessarily imply that it is better than a "lower" type/class sheeting. Different sheeting has certain performance characteristics, and the type of sheeting for a road

should be selected that suits the situation encountered by road users in viewing the signs on the particular road. Sheeting with a high coefficient of retro-reflection (CR) at a small observation angle will give better performance for the driver's viewing the sign from long distances. Similarly, a high coefficient of retro-reflection (CR) of sheeting with a wide observation angle will provide good performance for drivers encountering situations involving a wide observation angle. The application of different classes shall be followed as shown in Table 7.1-13 or as per the discretion of the Engineer.

Table 7.1-13: A general guideline for usage of different types of sheeting (adapted from Code of practice for road signs, Indian Road Congress 2012)

Class of Sheeting	Type of Sheeting (ASTM)	Category of Roads			
		National Highways	Regional Highways	Zilla Roads	Expressway
Class A	Type II	No	Yes	Yes	No
Class B	Type IV	Yes	Yes	Yes	No
Class C	Type XI	Yes	No	No	Yes

Outdoor Weathering of Retro-reflective Sheeting

The luminous intensity reduces with the aging of the sign face material, and the manufacturers' guarantees are related to a specified percentage of the luminous intensity of the new material being maintained at the end of the guarantee period. The minimum guarantee periods and the percentage of luminous intensity required to be available at the end of the period shall be followed as mentioned in Table 7.1-14.

Table 7.1-14: Outdoor Weathering Photometric Requirements of Retro-reflecting Sheeting after Guarantee Periods (adapted from Code of practice for road signs, Indian Road Congress 2012).

Type of Sheeting	Minimum Guarantee periods (Years)	Minimum Coefficient of retro-reflection (CR)
Type II	05	50% of Table 7.10
Type IV	07	80% of Table 7.11
Type XI	10	80% of Table 7.12

Color

“BS 381C: Specification for colors for identification, coding and special purposes” shall be primarily used for the purpose of identification. To closely match the right color shades with the commercially available retro-reflective sheeting with different standards, the following online conversion schemes can be used (indicative only).

<https://www.imi21.com/3mcolor-conversion-palettes.php>: Convert 3M colors to RAL classic or Pantone

<https://www.e-paint.co.uk/color-alternatives.asp>: Convert RAL Classic or Pantone to BS 381C and US Federal Standard 595C

Table 7.1-15 shows the approximate match for commercial 3M retro-reflective sheeting colors with BS 381 and Federal Standard 595C

Table 7.1-15: approximate match for commercial 3M retro-reflective sheeting colors with BS 381 and Federal Standard 595C.

3M Sheeting Color	BS 381C Approximate Match	Federal Standard 595C Approximate Match
White	350 (Light Grey)	37875 (White)
Yellow	356 (Golden Yellow)	13538 (Yellow)
Red	537 (Signal Red)	11105 (Red)
Blue	104 (Azure Blue)	15180 (Blue)
Green	225 (Light Brunswick Green)	14120 (Green)
Fluorescent Yellow	<i>No direct equivalent</i>	13655 (Fluorescent Yellow)
Fluorescent Yellow-Green	<i>No direct equivalent</i>	38901 (Fluorescent Green)
Fluorescent Orange	<i>No direct equivalent</i>	12300 (Fluorescent Orange)
White Translucent	350 (Light Grey)	37875 (White)



Figure 7.1-1: Indicative Pictorial Depiction of Colors for Sheeting (Federal Standard 595C).

Adhesives

The retro-reflective sheeting shall be equipped with either a pressure-sensitive adhesive or a heat-activated adhesive, ensuring strong and durable adhesion to the base material. For road safety devices in Bangladesh, the selection of retro-reflective sheeting backing classes must consider high temperatures, humidity, and installation feasibility. The two most applicable classes from ASTM D4956 are:

Class 1 – Pressure-Sensitive Adhesive (PSA)

- Allows quick installation by simply applying pressure, making it ideal for permanent road signs, regulatory signs, and guide signs.
- Works effectively on smooth and clean metal or aluminum substrates, which are commonly used for traffic signage.

Class 2 – Heat-Activated Adhesive

- Suitable for high-performance, permanent traffic signs in high-temperature environments.
- Requires heat activation (minimum 150°F / 66°C), which ensures strong, durable adhesion in challenging outdoor conditions.
- Useful for long-lasting applications in highways, expressways, and high-traffic urban areas where signs must withstand extreme weather and pollution.

To protect the adhesive before application, the sheeting shall include a removable liner that can be peeled away easily without requiring water or solvents. The adhesive must form a permanent and secure bond with the corrosion- and weather-resistant surface of the base plate, preventing the sheeting from being removed in a single piece using sharp instruments. All pressure-sensitive adhesive sheeting shall be applied strictly in accordance with the manufacturer's specifications. Any sheeting requiring solvents or additional surface treatment for adhesion must also be installed as per the manufacturer's instructions.

Sign face application

The application of messages (legends, letters, numerals, etc.) and borders on traffic signs can be done using three methods: screen printing, overlay method (cut-outs from durable transparent overlay film), and Simple cut and paste method (cut-outs from the same type of reflective sheeting). Each method follows specific processing and bonding requirements to ensure durability and compliance with the sheeting manufacturer's warranty.

1. Digital Printing

Digital printing is a method that uses inkjet or laser technology to apply graphics directly onto surfaces without the need for screens or stencils, offering high precision, faster processing, and UV-resistant ink options for durability. The legends, symbols, and borders are directly printed onto the reflective sheeting using this method. This method is applicable for regulatory, warning, small informatory signs, and supplementary boards, especially for black-colored elements, as retro-reflective sheeting for black color is not commercially available. The printing shall be carried out using materials and techniques approved by the sheeting manufacturer.

2. Cut-Outs from Durable Transparent Overlay Film

The transparent overlay film used for traffic signs must be a high-performance polyester or acrylic-based material with a thickness of 50–100 microns (μm) to ensure durability without affecting reflectivity. It should have at least 90% optical clarity, providing UV resistance for a minimum of 10 years without yellowing or degradation. The film must form a permanent bond with the reflective sheeting, meeting ASTM D4956 adhesion standards, and be resistant to moisture, temperature variations (-40°C to $+70^{\circ}\text{C}$), and road contaminants such as oils and solvents. Compatibility with the reflective sheeting type and manufacturer's specifications is essential for long-term performance in Bangladesh's environmental conditions

3. Cut-Outs from the Same Reflective Sheeting

In this method, letters, numerals, and borders are cut out from the same type of reflective sheeting and applied to the sign face. This technique can be used for all types of signs, except for black-colored elements.

All three methods must adhere to the warranty provisions of the sheeting manufacturer, ensuring long-term performance, visibility, and resistance to environmental conditions.

Field Testing for Luminance

Field luminance testing of retro-reflective traffic signs shall be conducted using a retro-reflectorimeter compliant with EN 12899-1, ASTM E1709, and ASTM E2540 to assess nighttime retro-reflectivity (RA) and shall pass the requirements stipulated in this Specification. The equipment shall measure luminance values in the range of $0 - 2000 \text{ cd.m}^{-2}.\text{lx}^{-1}$, ensuring compliance with regulatory standards for visibility and performance. Testing shall be performed under specified observation and illumination angles, with results documented using integrated GPS tracking, barcode/QR code readers for sign identification, and an onboard camera for condition assessment. Measurements shall be taken at multiple points on each sign to verify uniformity, with data stored electronically for analysis and reporting. The testing procedure shall follow the manufacturer's guidelines to ensure consistency and repeatability, and any non-conforming signs shall be scheduled for maintenance or replacement.

Lab Test Requirements

A certificate of having tested the sheeting as per ASTM D4956-09, for co-efficient of retro-reflection (ASTM D4956: 7.3; E810), day time color luminous property (ASTM D4956: 7.4; E308, E1347, E1349), adhesion (ASTM D4956:7.5), outdoor weathering (ASTM D4956: 7.6; G7), shrinkage (ASTM D4956: 7.8), flexibility (ASTM D4956:7.9), linear removal (ASTM D4956:7.10), impact resistance (ASTM D4956: 7.11; ASTM D2794), nighttime color (ASTM E811; E308; E 3165), and fungus resistance (ASTM D4956:S1) and its having passed these tests shall be obtained from a reputed

or Government Laboratory as approved by the Engineer. The criteria for passing the minimum coefficient of retro-reflection are described in Table 7.1-10, 7.1-11, 7.1-12, and outdoor weathering in 7.1-14. The following criteria shall be met for the rest of the performance characteristics:

Daytime Color and Luminous Properties: The chromaticity coordinates and luminance factor (Y) of the sheeting must conform to the specifications outlined in ASTM D4956, ensuring accurate color representation and brightness during daylight conditions.

- **Adhesion:** When tested, the adhesive backing of the retro-reflective sheeting shall produce a bond that will support a 13/4-lb (0.79-kg) weight for both the adhesive classes (ASTM D4956).
- **Shrinkage:** After conditioning, the sheeting should not shrink more than 0.03125 inches (0.79 mm) in 10 minutes and 0.125 inches (3.18 mm) in 24 hours.
- **Flexibility:** The material must show no cracking when bent around a 1/8-inch (3.175 mm) diameter mandrel within 1 second at room temperature.
- **Liner Removal:** The protective liner should be easily removable without soaking and should not tear or remove adhesive from the sheeting.
- **Impact Resistance:** When subjected to impact testing, the sheeting must exhibit no cracking or delamination outside the actual area of impact.
- **Nighttime Color:** The nighttime color of the sheeting should conform to the chromaticity coordinates specified in ASTM D4956, ensuring proper visibility under low-light conditions.
- **Fungus Resistance:** After inoculation with *Aspergillus niger* and a 14-day incubation, the material should show no appreciable fungus growth; any growth must be removable by wiping with a soft cloth.

Layout

Layouts of all traffic signs shall be followed from the guidelines and principles described in the RHD Road Safety Engineering Manual 2024. Unless otherwise specified in the Manual, the layout of the signs shall be as directed by the Engineer.

7.1.3. Post-mounted Sign Fabrication and Installation

Single/Double Post Mounted Sign Fabrication

The contractor shall submit on-site sign drawings with design calculations and details of the sign fabrication process (including materials and equipment to be used) to the Engineer for approval. Fabrication process of signs shall be such that all sign plates, fittings, fixtures, etc., can be assembled and erected without requiring modification during installations. It shall be the Contractor's responsibility to ensure that the installation of signs, including the construction of foundations for signposts, does not interfere with traffic movement or compromise road user safety.

If desired by the Engineer, the contractor shall arrange at his own cost a practical demonstration of the proposed fabrication process. The Engineer shall accord approval of the proposed fabrication process in writing if the fabrication process becomes satisfactory to him. After getting approval from the Engineer in writing only, the contractor shall immediately start fabrication of all the signs.

Mounting Posts and Foundations

Sign posts (single/double) shall be adequate in number, size, and strength to hold the signs in position without allowing any displacement or tilting within the defect liability period. Number and rigidity of signposts shall be fixed based on the size of the signs. If necessary, additional posts or vertical backside supports must be used on signboards to ensure strength against wind pressure.

The lengths of posts shall be provided as shown in the Engineering drawings. The size (diameter, thickness) of posts shall conform to the criteria specified in section 7.1.2.1 or as shown in the Engineering drawings. The base plates shall be not less than 4.5 mm thick and shall have an area not less than five times the outer plan area of the post, or as shown on the drawing.

Where a post has to be sited close to a wall, either the top of the post shall be angled away from the wall to provide adequate clearance for the sign, or an adequate bracket shall be provided from the post for this purpose. In either case, the post shall be of adequate strength and rigidity to withstand the additional bending moments and torsion resulting from such arrangement.

All open-ended posts or other hollow sections used in construction shall be effectively capped to prevent the entry of water.

Embedment of Sign Posts in Concrete Foundations

The base of posts shall be embedded in concrete foundations. Concrete shall be rammed around the base of the posts such that the post will be firmly held in position immediately after completion of placing and compaction of concrete.

The minimum thickness of concrete embedment and its height shall be as per the Engineering drawings or as directed by the Engineer based on specific design considerations, taking into account the ground conditions.

The post shall be carefully positioned and plumbed, and struts and stays applied as necessary to hold it in position during embedment. The concrete shall then be placed under and around the post in uniform lifts not exceeding 200 mm, and each lift thoroughly rammed. Care shall be taken to avoid contamination of the concrete from the surrounding surface and soils. Any contaminating material falling into the concrete shall be immediately removed along with the contaminated concrete itself.

All the concrete embedment for a post shall be provided in one operation, and the surface of the concrete embedment shall be formed to present a neat and tidy appearance and sloped to shed water away from the post.

7.1.4. Overhead Sign Design and Installation

Design

Overhead signs using gantry and cantilever arms may be used instead of single/double post-mounted traffic signs in places where the situation warrants in order to provide proper information and guidance to the road users. The following conditions may be considered while deciding about the provision of overhead signs:

- Traffic volume at or near capacity
- Complex interchange design
- Number of lanes in each direction
- Specific need to install devices like cameras, detectors, display boards, etc.
- Restricted sight distance
- Closely spaced interchanges
- Multi-lane exits
- A large percentage of commercial vehicles
- High-speed vehicular movement
- Insufficient space for a ground-mounted sign
- Background of street lighting
- Distances of important places along the highways at suitable intervals

From safety and aesthetic considerations, overhead signs shall be mounted on overhead portal structures. The support system, other than bridge structures (gantry or cantilever arms), should be properly designed based on sound engineering principles to safely sustain the dead load, live load, and environmental load (wind load + earthquake load) on the completed sign system. For this purpose, the overhead signs shall be designed to withstand a wind loading of 150 kg/m^2 normal to the face of the sign and 30 kg/m^2 transverse to the face of the sign. In addition to the dead load of the structure, the maintenance walkway loading of 250 kg concentrated live load shall also be considered for the design of the overhead sign structure. Unless otherwise specified, the design load and load combinations for the system shall be in accordance with specifications set forth in BNBC 2020, checked for torsional capacity and buckling strength of vertical members as well. The structural framing system and components shall be designed with adequate stiffness to have deflections, vibrations, or any other deformation within the serviceability limit for the structure. Design for foundation shall be checked in conjunction with the above support system, considering a safe load-bearing capacity of the supporting soil or by testing the load-bearing capacity (in cases where special treatment for improving

the ground soil condition would be necessary). The height and lateral offset will be provided as per the RHD Road Safety Engineering Manual 2024.

Number of Signs at an Overhead Installation

If the installation of overhead signs is deemed necessary, the total number of signs placed on a single overhead structure should not exceed three. The limit applies to all types of regulatory, warning, or informatory signs mounted directly on the overhead structure or its supporting framework. (Section 2A.17, MUTCD 2023).

Materials

Steel/Aluminum sections and all components, including base connections and mounting fixtures, shall comply with appropriate material specifications, such as ASTM A370, A938 for mild steel/ ASTM B209 or BS1470 for aluminum, or equivalent. These shall be of sections and type as per structural design requirements, as shown in the Engineering drawings. After fabrication and all required holes punched or drilled on both the horizontal and vertical support units, they shall be galvanized/painted in accordance with section 7.1.2.5. Additionally,

Substrate for sign shall conform to the criteria specified in section 7.1.2.2.

Frames and stiffeners shall conform to the criteria specified in section 7.1.2.3.

Fixtures and fittings shall conform to the criteria specified in section 7.1.2.4.

The overhead signs shall be of micro prismatic retro-reflective sheeting (Type-XI) as specified in section 7.1.2.6.

Installation

The supporting structure and signs shall be fabricated and erected as per the details given in the design drawing, plans, and at locations directed by the Engineer.

Sign posts, their foundations, and sign mountings shall be so constructed as to hold signs in a proper and permanent position to adequately resist swaying in the wind or displacement by vandalism.

The work of construction of the foundation for sign supports, including excavation and backfill, forms, steel reinforcement, concrete, and its placement, shall conform to the engineering drawings and to the relevant specifications. The structures shall be erected with the specified camber and in such a manner as to prevent excessive stresses, injury, and defacement.

Brackets shall be provided for mounting signs of the type to be supported by the structure. For better visibility, they shall be adjustable to permit mounting the sign faces at any angle between a truly vertical position and three degrees from vertical. This angle shall be achieved by rotating the sign face

about its mounting axis so that the lower front edge is set forward relative to the upper edge. All brackets shall be of a length equal to the height of the signs being supported.

Before erecting support structures, the bottom of each base plate shall be protected with an approved material that will adequately prevent any harmful reaction between the plate and the concrete.

The end supports shall be plumbed by the use of leveling nuts, and the space between the foundation and base plate shall be completely filled with an anti-shrink grout.

Anchor bolts for sign supports shall be set to proper locations and elevation with templates and carefully checked after construction of the sign foundation and before the concrete has set.

All nuts on the aluminum supporting structure, except those used on the flanges, shall be tightened only until they are snug. This includes the nuts on the anchor bolts. A thread lubricant shall be used with each aluminum nut.

All nuts on galvanized steel supporting structure, with the exception of high-strength bolt connections, shall be tightened only to a snug condition.

Field welding shall not be permitted.

After the installation of the signs is complete, the sign shall be inspected by the Engineer. If specular reflection² is apparent on any sign, its positioning shall be adjusted by the Contractor to eliminate or minimize this condition.

During the installation of traffic signs, the contractor shall submit a traffic management plan to ensure minimal disruption to traffic and maximum safety for workers and road users. Advance warning signs, cones, and barricades shall be placed at appropriate distances to alert drivers of ongoing work. Workers shall wear high-visibility safety gear and be protected by barriers or flaggers as needed. Installation activities will be scheduled during off-peak hours whenever possible to reduce congestion and risks. Emergency response measures will be in place, and upon completion, all temporary traffic control devices and debris will be promptly removed to restore normal traffic conditions safely.

7.1.5. LED Traffic Signs

General

LED traffic signs can enhance traffic management by providing highly visible, energy-efficient illumination that ensures driver attention while conserving energy. Solar signs shall be used where they are required. According to MUTCD 2023 (Section 2A.07, Retro-reflectivity and Illumination), traffic

² Specular reflection refers to a concentrated glare caused when light from a source, such as vehicle headlights, is reflected directly back toward the driver's eyes. This can make the sign appear overly bright in certain spots and reduce its legibility.

signs should be illuminated to ensure visibility in low-light conditions. Solar-powered traffic signs provide an alternative where conventional power sources are unavailable. In general, solar-powered traffic signs should be considered in areas with high solar availability to reduce energy consumption. In addition, the application shall be considered for places where additional visibility is required.

Illumination of a traffic sign face to ensure visibility at night or in low-light conditions can be done in two main ways:

1. LED illumination (external or embedded): LEDs are arranged to light up the legend, border, or background of a *standard, fixed-message* sign. This keeps the sign visible at night without relying on external street lighting.
2. LED display panels (full or partial): This is a *variable message sign* (VMS) or changeable message sign, where the sign face itself is an LED screen. This is covered in Part II of Chapter 7 of this Specification.

LED traffic signs can be applied under different conditions and for various purposes as follows:

1. Regulatory signs to control traffic flow by displaying speed limits, entry restrictions, and weight or height limits;
2. Warning signs such as flashing lights/beacons with sensors at high-risk areas to alert drivers to curves, pedestrian crossings, school zones, wildlife, bike lanes, shared roadways, railway crossings, and adverse weather conditions;
3. Temporary/portable traffic control by guiding traffic through construction/work zones, detours, and lane closures;
4. Radar or sensor-based variable speed limit signs and speed feedback signs to help control vehicle speeds by providing real-time instruction and feedback in high-risk areas; and
5. Lane control, toll rate display, and congestion warnings for efficient traffic movement on highways.

Technical Requirements:

LED traffic signs can automatically flicker to alert drivers about road conditions, encouraging cautious driving and helping to reduce accidents and fatalities. LED traffic signs shall be of high visibility and energy efficiency, utilizing solar panels/grid power/battery to power LED lights for enhanced road safety. The detailed technical requirements are given in Table 7.1-16.

Table 7.1-16: Technical Requirements for LED Light Modules in Solar Traffic Signs.

Component	Specification
LED Type	High-intensity, solid-state, single-chip LEDs; compliant with IEC 60810 and EN 12368 requirements for traffic control equipment.

LED & PCB	Ultra-bright, water-clear LEDs mounted on FR-4 glass epoxy PCB (minimum thickness 1.5 mm); uniform distribution pattern to ensure even illumination across the sign face.
LED Quantity	Minimum 120 LEDs for 600 mm sign; proportionally increased for 800 mm and 1000 mm signs.
Colors	Red, Amber (Yellow), White; chromaticity per CIE 1931 coordinates and ASTM D4956.
Luminous Intensity	Meets SAE J595 Class 1 and EN 12368 brightness requirements; visible from a minimum of 800 m in clear conditions.
Viewing Angle	Minimum 30° full width at half maximum (FWHM).
Lifetime (L70)	≥ 100,000 hours at rated drive current and operating temperature.
Power Factor	≥ 0.9 for LED driver circuitry.
Operating Voltage	12 V DC nominal (compatible with solar battery system).
Power Consumption	≤ 0.5 W per LED (energy-efficient, low heat).
Flashing / Illumination Mode	Steady or flashing; adjustable flash rate between 50–60 flashes per minute for warning applications.
Operating Temperature	–10 °C to +60 °C without degradation of luminous performance.
Ingress Protection	IP65 minimum for LED modules; IP67 for flood-prone installations.
Standards Compliance	IEC 60598-1 (Luminaires), EN 12368 (Traffic control equipment — Signal heads), CE certified.

Installation of LED solar signs

LED traffic sign fabrication and installation requirements shall be the same as stipulated in Section 7.1.2, but note that, due to the LED illumination, retro-reflective sheeting will not be required.

Power Options including Solar Panel

Table 7.1-17: Technical Requirements of Powers Options for LED Signs.

Power Supply	Total solid-state electronic circuitry; supports grid (120–240 VAC), solar, or hybrid configurations; 12V DC system voltage
Control Box/Enclosure	Lockable, vandal-resistant aluminum housing; corrosion-resistant quarter-turn mechanism; NEMA 4X & IP66 compliant (IP67 for flood-prone areas)
Solar Panel	High-efficiency monocrystalline/polycrystalline; 12 V; 30–50 W capacity (depending on sign size and illumination pattern); adjustable tilt and orientation; CE & IEC 61215/61730 certified.
Battery System	Sealed Maintenance-Free (SMF) or AGM-type deep cycle; recyclable; minimum 20 Ah for standard applications, 40 Ah for extended operation; operational range –20 °C to +65 °C; maintenance-free with ≥ 2-year warranty.
Autonomy	Minimum 300 hours of operation without sunlight at standard flash rate.

Consideration for Solar Panel:

- a) The tilt angle of the solar panels should generally be equal to the latitude of the location to optimize solar gain throughout the year. Bangladesh's latitude ranges from approximately 20°N to 26°N. Solar panels in Bangladesh should face south. For locations closer to the southern part of Bangladesh (around 20°N), set the tilt angle at about 20°. For locations further north (around 26°N), the tilt angle should be closer to 26°.
- b) In city areas, solar products shall not be installed under high buildings and in shade, as the solar panel will not work if it is shaded. Ideally, solar products should be installed in a place where the sun shines strongly.
- c) Solar panel shall be cleaned every three months to make sure it absorbs the sunshine well.
- d) Power switch shall be turned off to protect the battery during long rainy days until the battery has reserved 80% capacity after three days of charging.

7.1.6. Size and Location of Signs

The size of the signs, size of letters, letter fonts, sign dimensions, layout, and their placement on different types of highways shall be as per instructions represented in the RHD Road Safety Engineering Manual 2024.

In the absence of details or for any missing details in the Contract documents, the signs shall be provided as directed by the Engineer.

7.1.7. Measurement

Traffic signs shall be measured separately based on their types, materials, dimensions, and installation methods. Measurement for traffic signs shall include complete installation, comprising sign plates, retro-reflective sheeting, posts, frames, stiffeners, fixtures, fittings, foundation concrete embedment, overhead supporting structures (gantries and cantilever arms), frangible and non-frangible post systems, protective coatings (galvanization or painting), surface preparation, adhesives, printing or overlay application methods, and all related hardware and accessories as detailed in the specification and Engineering drawings or directed by the Engineer.

Single/double post-mounted traffic signs shall be measured individually by number, categorized by standard sizes, and classified by retro-reflective sheeting types. Measurement shall include supplementary plates, substrate/backing plates, frames and stiffeners, fixtures and fittings, protective finishes, base plates, and foundations.

Overhead-mounted traffic signs shall be measured by square meters, including aluminum substrate/backing plates, frames and stiffeners, fixtures and fittings, and protective finishes. Cantilever and gantry steel structures shall be measured by weight in kilograms, inclusive of base plates, fixtures, and fittings. Foundations for overhead-mounted posts shall be measured by volume in cubic meters, including reinforcement.

Solar LED traffic signs shall be measured individually by number, covering complete installation with solar panels, batteries, and associated electrical components.

7.1.8. Payment

Traffic signs measured as described above shall be paid under their respective contract unit rates for each category and type of installation. The unit rates shall include complete compensation for the fabrication, transportation, erection, assembly, and installation of traffic signs, including sign plates, retro-reflective sheeting, supplementary plates, substrate/backing plates, frames, stiffeners, fixtures and fittings, protective coatings (galvanization or painting), base plates, concrete foundations, overhead support structures (gantries and cantilever arms), solar LED systems (including panels and batteries), and all associated electrical components.

Rates shall also cover costs related to surface preparation, adhesives, printing or overlay methods, structural calculations, inspections, testing (field and laboratory), certifications, excavation and backfilling, transportation, loading/unloading, auxiliary materials, tools, equipment, traffic management, and incidentals. Additionally, all maintenance, repair, and replacement work required during the defect liability period, ensuring compliance with the specifications, Engineering drawings, and the Engineer's approval, shall be included in these rates.

Pay items shall be:

Pay Items	Description	Unit
Single/double post-mounted traffic signs		
7.1.1	Standard size Traffic sign 750 mm diameter, 750 mm triangle height or area up to 0.9 m ² including supplementary plate, substrate/backing plate, frames and stiffeners, fixtures and fittings, and necessary protective finishes, base plates and foundation.	Type II Number
		Type IV Number
		Type XI Number
7.1.2	Standard size Traffic sign 900 mm diameter, 900 mm triangle height or area up to 1.1 m ² including supplementary plate, substrate/backing plate, frames and stiffeners, fixtures and fittings, and necessary protective finishes, base plates and foundation.	Type II Number
		Type IV Number
		Type XI Number
7.1.3	Traffic sign on double posts including substrate/backing plate, frames and stiffeners, fixtures and	Type IV Number

	fittings, and necessary protective finishes, base plates, and foundation.		
Overhead-mounted traffic signs			
7.1.4	Traffic sign for overhead mounted posts including aluminum substrate/backing plate, frames and stiffeners, fixtures and fittings, and necessary protective finishes.	Type XI	Sq. meter
7.1.5a	Steel for one side cantilever post, including base plates, fixtures, and fittings.		Kg
7.1.5b	Steel for two side cantilever posts, including base plates, fixtures, and fittings.		Kg
7.1.5c	Steel for gantry, including base plates, fixtures, and fittings.		
		2 Pillars	Kg
		3 Pillars	Kg
7.1.6	Foundation for overhead-mounted posts, including reinforcement		Cu meter
7.1.7	Solar LED Traffic Sign		Number

7.2. REMOVAL OF EXISTING TRAFFIC SIGNS

7.2.1. Description

This work shall consist of the removal of existing traffic signs. The existing unspecified / damaged traffic signs shall be removed and disposed of as per the direction of the Engineer.

7.2.2. Construction Method

The construction work shall include all necessary excavation to take out the existing sign and posts with their foundation and dispose of them from the site. The backfilling of the excavated hole shall be made with selected soils and be compacted. Unused spoils will be the property of the Contractor.

The Contractor shall be fully responsible for managing traffic and ensuring road user safety during the removal process. This shall include the provision of appropriate traffic control devices, signage, barriers, and flagmen, in accordance with the approved Traffic Management Plan and the Engineer's instructions, to prevent hazards to motorists, pedestrians, and workers.

All salvaged sign panels, posts, and structural components shall be handled carefully to prevent unnecessary damage during removal. Salvaged materials that the Engineer deems reusable shall be transported by the Contractor to a designated RHD storage location. If no storage location is specified, or if the materials are not required for reuse, the Contractor may retain them or dispose of them off-site in an environmentally acceptable manner, subject to the Engineer's written approval.

7.2.3. Measurement

Removal of existing traffic signs shall be measured individually by number, clearly categorized as single/double posts, one-sided cantilever posts, or gantry-mounted signs. Measurement shall cover the complete removal, including excavation, extraction of signposts and their foundations, backfilling and compaction of excavated holes, and disposal of materials as directed by the Engineer.

7.2.4. Payment

The measured removal works shall be paid under the respective contract unit rates for each specified category. The unit rates shall include full compensation for excavation, removal, disposal of signs, signposts, and foundations, backfilling and compaction with selected soils, transportation, labor, equipment, and all other incidentals necessary to complete the work as per specifications and the Engineer's instructions. The unit rates shall be deemed to include the handling, transportation, and delivery of any salvageable materials to a designated RHD storage location, or the cost of disposal/retention if reuse is not required.

Pay items shall be:

Pay Items	Description	Unit
7.2.1a	Removal of existing unspecified/damaged traffic signs on single and double posts	Number
7.2.1b	Removal of existing unspecified/damaged traffic signs on one side of the cantilever post	Number
7.2.1c	Removal of gantry-mounted existing unspecified/damaged traffic signs	Number

7.3. ROAD MARKINGS

This section covers the supply, surface preparation, application, and quality control of various road marking systems, including hot-applied thermoplastics, cold-applied reflective paints, luminous paints, and preformed thermoplastic tapes to be used across the RHD road network. Road markings are essential traffic control devices that regulate, warn, and guide road users, thereby enhancing safety, improving lane discipline, and ensuring efficient traffic flow under both day and night conditions.

The color, width, size, and layout of road markings shall be in accordance with RHD Road Safety Engineering Manual 2024, and as specified in the Engineering drawings or as directed by the Engineer. Materials and workmanship shall comply with the relevant provisions of AASHTO, ASTM, BS, ISO, or other internationally recognized standard specifications, as referenced in this Specification, applicable to road marking materials, application methods, retro-reflectivity, skid resistance, and durability.

All markings shall be applied using approved mechanical or manual methods as appropriate to ensure uniformity, edge clarity, durability, and effective retro-reflectivity under both dry and wet conditions. The materials shall be selected based on road type, traffic volume, environmental exposure, and safety requirements. Compliance with visibility, thickness, luminance, and skid resistance shall be verified through field testing using standardized procedures and calibrated equipment. All work under this section shall be carried out in accordance with the approved method statements and subject to quality control and acceptance by the Engineer.

7.3.1. Hot Applied Thermoplastic Road Marking

7.3.1.1. General

- a) The work under this section shall consist of marking traffic stripes using a thermoplastic compound meeting the requirements specified herein.
- b) The thermoplastic compound shall be screeded or extruded onto the pavement surface in a molten state by a suitable machine capable of controlled preparation and laying with surface application of glass beads at a specific rate. Upon cooling to ambient pavement temperature, it shall produce an adherent pavement marking of specified thickness and width and be capable of resisting deformation by traffic.
- c) The color of the compound shall be white or yellow, other than the parking area as specified in the Engineering drawings or as directed by the Engineer.
- d) Where the compound is to be applied to cement concrete pavement, a sealing primer as recommended by the manufacturer (or conforming to section 7.3.5), shall be applied to the pavement in advance of placing the stripes to ensure proper bonding of the compound. On a new concrete surface, any laitance and/or curing compound shall be removed before the markings are applied.

7.3.1.2. Thermoplastic Material

The thermoplastic material shall be homogeneously composed of binder, filler, pigment, plasticizers, and reflectorizing glass beads.

Requirements

- a) **Composition:** The pigment, beads, plasticizer, and filler shall be uniformly dispersed in the resin. The material shall be free from all skins, dirt, and foreign objects and shall comply with the requirements indicated in Table 7.3-1.

Table 7.3-1: AASHTO M 249-98 standard proportions of constituents of marking material (percentage by weight).

Component	White	Yellow
Binder (with plasticizer)	18.0 min.	18.0 min.
Glass Beads	30-40	30-40
Titanium Dioxide (ASTM D476)	10.0 min.	—
Calcium Carbonate and Inert Fillers	42.0 max.	See Note below
Yellow Pigments	—	See Note below

Note: The Amount of pigment and fillers shall be at the option of the manufacturer, provided all other requirements of this Specification are met.

- b) **Properties:** The properties of thermoplastic material, when tested in accordance with ASTM D36/BS-3262- (Part I), shall be as below:
- Luminance:**
 White: Daylight luminance at 45°-0°: 75 percent min. as per AASHTO M 249.
 Yellow: Daylight luminance at 45°-0°: 45 percent min. as per AASHTO M 249.
 - Drying time:**
 As per AASHTO M 249, when applied at a temperature range of 211±7°C, and a thickness of 3.2 to 4.8 mm, the material shall set to bear traffic in not more than two minutes when the air temperature is 10±2°C, and not more than 10 minutes when the air temperature is 32±2°C.
 - Skid resistance:**
 Not less than 45 as per BS: 6044.
 - Cracking resistance at low temperature:**
 The material shall show no cracks on application to concrete blocks.
 - Softening point:**
 102.5°C ± 9.5°C as per ASTM D36.
 - Yellowness index (for white thermoplastic paint):**
 Not more than 0.12 as per AASHTO M 249.
 - Specific Gravity:**
 2.15maximum as per AASHTO M 249.
 - Impact Resistance:**
 1.13 Joules minimum as per AASHTO M 249.

- i. Flowability:
18% retained minimum as per AASHTO M 249.
 - j. Extended flowability:
28% retained minimum as per AASHTO M 249.
 - k. Flash Point:
246°C minimum as per AASHTO M 249.
 - l. Water absorption:
0.5% maximum as per AASHTO M 249.
 - m. Bond strength:
 - n. 1.24 Mpa minimum as per AASHTO M 249.
- c) Storage life: The material shall meet the requirements of these Specifications for a period of one year. The thermoplastic material must also melt uniformly with no evidence of skins or unmelted particles for the one-year storage period. Any material not meeting the above requirements shall be replaced by the manufacturer/ supplier/Contractor.
- d) Reflectorization: Shall be achieved by incorporation of beads, the grading and other properties of the beads shall be as specified in Sub-section 7.3.1.1.
- e) Marking: Each container of the thermoplastic material shall be clearly and indelibly marked with the following information:
- a. The name, trademark, or other means of identification of the manufacturer
 - b. Batch number
 - c. Date of manufacture
 - d. Color (white or yellow)
 - e. Net weight
 - f. Maximum application temperature and maximum safe heating temperature.
- f) Sampling and testing: The thermoplastic material shall be sampled and tested for each batch in accordance with the appropriate ASTM/BS method. The Contractor shall furnish to the Engineer a copy of certified test reports from the manufacturers of the thermoplastic material showing results of all tests specified herein and shall certify that the material meets all requirements of this Specification. The following testing requirements shall be considered to ensure the desirable characteristics of thermoplastic materials in accordance with AASHTO M 249-98 or BS 3262-1(1989):
- Determination of binder/filler/pigment content (AASHTO T 250/ASTM D4797-88 or BS 3262-1)
 - Determination of the grading of constituents and glass bead content (AASHTO M 247-81 or BS 6088)
 - Determination of luminance factor/reflectance (AASHTO T 250/BS 3262-1)
 - Determination of Softening point (AASHTO T 250/ASTM D36 or BS 3262-1)

- Determination of heat stability (AASHTO T 250 or BS 3262-1)
- Determination of skid resistance (AASHTO T 250 or BS 3262-1)
- Determination of flow resistance (AASHTO T 250 or BS 3262-1)
- Determination of specific gravity (AASHTO T250/ASTM D792 – 13)
- Determination of flash point, water absorption, drying time, cracking resistance at low temperature, impact resistance (AASHTO T 250)

7.3.1.3. Reflectorizing Glass Beads

This Specification (Adapted from AASHTO M247-81) covers two types of glass beads to be used for the production of reflectorized pavement markings. Type 1 beads are those which are a constituent of the basic thermoplastic compound, and Type 2 beads are those which are to be sprayed on the surface, vide, Table 7.3.2. The glass beads shall be transparent, colorless, and free from milkiness, dark particles, and excessive air inclusions. These shall conform to the requirements set out in Clause shown below:

Specific requirements

- Roundness: The glass beads shall have a minimum of 70 percent true spheres.
- Refractive index: The glass beads shall have a minimum refractive index of 1.50.
- Gradation: The glass beads shall meet the gradation requirements for the two types as given in Table 7.3-2.
- Crushing Resistance: Retained 0.425-mm (No. 40) sieve 133 N (30lbs.) minimum.
- Moisture Resistance: The glass beads must be moisture-resistant during storage, ensuring they do not clump or form clusters. It should remain loose and free-flowing, allowing smooth dispensing from application equipment.
- Flotation: When tested in accordance with M247-81(described below), a minimum of 90 percent of the beads shall float in xylene.

Table 7.3-2. Gradation requirements for glass beads (AASHTO M247-81).

Sieve size	Percent retained	
	Type 1	Type 2
1.18 mm	0 to 3	
850 microns	5 to 20	0 to 5
600 –do-	—	5 to 20
425 –do-	65 to 95	—
300 -do-	—	30 to 75
180 –do-	0-10	10 to 30

Below 180 microns	—	0 to 15

Sampling and Testing

Sampling Method: The selection of samples shall be conducted randomly at a ratio of 45 kg (100 lbs.) per 4535 kg (10,000 lbs.) of material shipped. The sample shall be taken in full bags and, upon arrival, reduced to approximately 1 kg using a sample splitter for testing purposes.

Testing Requirements and Standards (as per AASTHO M247-81):

The following properties shall be tested in accordance with the specified standards:

- Gradation: As per ASTM D1214.
- Roundness: As per ASTM D1155.
- Crushing Resistance: As per ASTM D1213.
- Refractive Index Measurement: Conducted using the liquid immersion method (Becke Line Method or an equivalent technique) at a temperature range of $25 \pm 5^{\circ}\text{C}$ ($77 \pm 9^{\circ}\text{F}$).
- Free-Flow Test: A 100-gram sample of glass beads is evenly distributed in a 100-mm diameter glass dish. This dish is placed inside a 250-mm desiccator, which contains a sulfuric acid-water solution (specific gravity: 1.10) up to 25 mm below the top of the desiccator plate. The desiccator is sealed and left undisturbed for four hours at a temperature between 20°C and 29°C . Afterward, the sample is removed, transferred to a pan, and examined for the presence of clumps or clusters. The beads are then poured into a dry glass funnel (featuring a 100-mm stem and 6-mm orifice). If necessary, a light tap on the funnel may be applied to initiate flow. The glass beads must be free from lumps or clusters and should flow smoothly through the funnel without obstruction.
- Flotation Test: Approximately 1 gram of beads is weighed with an accuracy of 0.005 g and evenly distributed in a clean, standard 100-mm glass Petri dish, which has been pre-weighed to the nearest 0.0005 g. A slight vibration is applied to the dish to achieve a near-monolayer distribution of beads. C.P. grade xylene is introduced gradually at 10–15 mL per minute from a burette until 30 mL has been dispensed. Floating beads are carefully extracted by suction using a constricted delivery tube connected to a receiving flask. Excess liquid is removed without displacing additional beads. The dish is subsequently dried in an oven at $110 \pm 5^{\circ}\text{C}$ before being weighed again to determine the percentage of floating beads.

The Contractor shall furnish to the Engineer a copy of certified test reports from the manufacturer of glass beads obtained from a reputed laboratory showing results of all tests specified herein and shall certify that the material meets all requirements of these Specifications. However, if so required, these tests may be carried out as directed by the Engineer.

Packaging & Marking

Glass beads shall be supplied in 1-kg (or lbs.) quantities, as specified by the purchaser, and packaged in moisture-resistant bags to ensure protection against humidity. The packaging must be designed to maintain the integrity of the beads, keeping them dry and undamaged during storage and transportation. Each package must be clearly labeled with the following details:

- Manufacturer's name and address
- Shipping location
- Trademark or brand name
- The phrase "Glass Beads"
- Specification number
- Net weight in kilograms (kg) or pounds (lbs.)
- Lot or batch number
- Month and year of manufacture

7.3.1.4. Preparation of Road Surface

The material shall be applied only on a surface that is clean and dry. It shall not be laid over loose deleterious materials like mud or similar extraneous matter, or over an old paint marking or an old paint marking or an old thermoplastic marking which is faulty or incompatible with the material being applied. New surfaces must be allowed to weather and compact for at least 72 hours before applying the marking. When using thermoplastic material, smooth polished surfaces, e.g., smooth concrete, old asphalt surfacing with smooth polished surfaces stones, and/or where the method of application requires or the Engineer directs, a tack coat shall be applied to the surface prior to the application. The tack coat shall be as recommended by the manufacturer of the thermoplastic material and to the approval of the Engineer. Faulty and old markings shall be removed before applying new markings. Removal of old marking shall have separate pay items.

7.3.1.5. Preparation and Placing of Road Markings

Preparation

The material shall be melted in accordance with the manufacturer's instructions in a heater fitted with a stirrer to give a smooth consistency to the thermoplastic, and such that local overheating shall be avoided. The temperature of the mass shall be within the range (AASHTO M249 specifies $211 \pm 7^\circ\text{C}$) specified by the manufacturer and shall in no case be allowed to exceed the maximum temperature stated by the manufacturer. The molten material shall be used as expeditiously as possible, and for thermoplastics that have natural resin binders or are otherwise sensitive to prolonged heating, the material shall not be maintained in a molten condition for more than 4 hours.

The thermoplastic material shall readily get screeded or extruded at temperatures specified by the manufacturers for the respective method of application to produce a line of specified thickness, which shall be continuous and uniform in shape, having clear and sharp edges.

The material, upon heating to application temperatures, shall not exude fumes that are toxic, obnoxious, or injurious to persons or property.

Laying

Markings may be applied by hand, by a self-propelled or automatic (single or double dispenser) road marking machine as approved by the Engineer. After transfer to the laying apparatus, the material shall be maintained within the temperature range specified by the manufacturer and stirred to maintain the right consistency for laying.

Road marking shall be applied in accordance with the manufacturer's recommendation and RHD Road Safety Engineering Manual 2024 as continuous or intermittent lines, arrows, figures, and symbols of the types, colors, and dimensions in the Engineering drawings, or as otherwise directed by the Engineer.

Thermoplastic paint with glass beads shall be laid to the specified thickness.

- Minimum Thickness (Screed Line Method): Not less than 4 mm.
- Thickness Measurement Method: Micrometer measurement using the Physical Gauge Method.
- Applicable Standards: ASTM D1212 (Test Methods for Measuring Thickness of Non-Transparent Coatings) and ISO 2808 (Paints and Varnishes-Determination of Film Thickness).

Procedure:

- A steel plate or aluminum panel is placed on the road surface before applying thermoplastic paint.
- The thermoplastic is applied, allowed to cool, and then removed from the plate.
- A micrometer or digital caliper is used to measure the thickness at multiple points.
- The average of multiple readings gives the final DFT.

The contractor shall state the maximum safe heating temperature, the temperature range of the apparatus, and the method of laying process to be used.

The thermoplastic road marking shall be applied using either the screed or spray method, incorporating glass beads and ensuring an even surface application of g at a rate of $500 \pm 50 \text{ g/m}^2$. The specified minimum thickness shall be measured excluding the surface-applied glass beads by setting the speed or spray rate of the screed on a trial section. Prior to application, the road surface must be clean and dry to ensure proper adhesion. The markings must be uniform, free from streaks, and without ragged

edges. All carriageway lane and edge lines shall be applied using approved mechanical equipment, ensuring a consistent and accurately aligned finish.

7.3.1.6. Trial Area for Road Marking

The contractor shall undertake a trial area of a representative sample of the road markings to demonstrate the suitability of the proposed method and equipment and the competence of the operators to the satisfaction of the Engineer.

Tolerance

The completed paint work shall have a neat appearance with sharply defined edges, and the markings shall be within the tolerance specified below:

- a. Lines and other markings shall not deviate from the specified width by more than 5%.
- b. The position of lines, letters, figures, arrows, and other markings shall not deviate from the specified positions by more than 20 mm.
- c. The edges of longitudinal lines shall not deviate from the true edge by more than 10 mm in 15 meters.
- d. The length of broken lines in the longitudinal direction shall not deviate from the specified length by more than 100 mm.

After the application of the paint, the road markings shall be protected against damage by traffic or other causes. The contractor is responsible for the faulty workmanship or substandard work. The paint that has been splashed or dripped on the surfacing, structures, or other surfaces shall be removed by the Contractor at his own cost.

The contractor shall not proceed with the marking work until the equipment, method of application, and rate of application, as established by a test section, have been approved by the Engineer.

The work shall be carried out very carefully to a regular alignment in accordance with the Engineering drawings. Straight edges and templates shall be used if required by the Engineer.

7.3.1.7. Luminance Testing on Site

Field luminance testing of thermoplastic road markings shall be conducted using a retro-reflectometer compliant with EN 1436 and ASTM E1710 to measure both nighttime retro-reflectivity (RL) and daytime visibility (Qd) and shall pass the requirements stipulated in this Specification. The device shall provide high-precision luminance readings within a measuring range of 0 - 4000 $\text{mcd} \cdot \text{m}^{-2} \cdot \text{lx}^{-1}$ (RL) and 0 - 400 $\text{mcd} \cdot \text{m}^{-2} \cdot \text{lx}^{-1}$ (Qd), ensuring compliance with visibility standards. Testing shall be performed on dry and clean surfaces, with measurements taken at regular intervals to assess uniformity and compliance with specified reflectivity thresholds. The equipment shall feature GPS integration for geolocation tracking, a built-in printer for on-site result documentation, and data export capabilities

for detailed reporting and analysis. Measurements shall be taken in accordance with manufacturer guidelines to ensure repeatability and accuracy, with any deviations from required reflectivity levels promptly addressed.

7.3.1.8. Reuse of Thermoplastic Material

At the end of each workday, any remaining material in the heater or laying apparatus should be removed as much as possible. The recovered material may be reused, provided that the maximum heating temperature has not been exceeded and that the total duration in a molten state remains within the specified limits.

7.3.1.9. Defective Materials and Workmanship

Defective materials or markings that have been improperly applied, do not meet specified dimensions, or are placed in the wrong location must be removed. The road surface shall be restored, and the markings must be reapplied correctly, all at the Contractor's expense and to the Engineer's satisfaction.

7.3.1.10. Protection of Traffic

The Contractor shall take necessary measures to protect pedestrians, vehicles, and nearby traffic from potential damage or staining caused by construction equipment, tools, materials, or paint splashes. Throughout the work, the Contractor must install and maintain appropriate warning signs and signals to ensure safe traffic movement.

Additionally, the Contractor is fully responsible for safeguarding newly completed work until it has fully hardened and can withstand traffic without damage. Any damaged markings or surfaces must be replaced or repaired at the Contractor's expense and responsibility.

7.3.2. Cold-applied Reflective Road Marking

7.3.2.1. General

The work shall consist of marking traffic stripes using a solvent based cold-applied paint, which shall be applied on the asphalt/cement concrete road surface by paint roller, hand trowel, hand box screed, or by machine (screed, spray, extruded, and structured) Both glass beads and anti-skid media are intermixed into the product, providing retro-reflectivity and anti-skid properties for the life of the marking. Glass beads shall be subsequently spread pneumatically on to the paint when it is still wet so that the paint will firmly hold the beads after drying. Color of the paint shall be white or yellow as specified in the RHD Road Safety Engineering Manual 2024 or Engineering drawings or as directed by the Engineer.

7.3.2.2. Methods

Cold-applied reflective paint is categorized according to its mode of application, each suited for specific road marking requirements:

1. Manual Application Methods

- **Roll-On Application:** Applied using a paint roller, mainly for cycle lanes, pedestrian zones, and parking lots. The pre-mixed product does not contain glass beads, but surface-applied glass beads or anti-skid materials can be added if needed.
- **Trowel Application:** Manually applied using a cement finisher's hand trowel, creating sharp edges and a high-build thickness. It is ideal for intersection markings, legends, and arrows, containing pre-mixed glass beads and anti-skid materials for long-term durability, but not suitable for longitudinal lines due to its thickness.
- **Hand Box Screed Application:** Applied manually using a hand box screed, ensuring even distribution for intersection markings and pedestrian crossings. This method provides high durability and precise application control, with the material typically containing intermixed glass beads for retro-reflectivity.

2. Automatic (Machine-Based) Application Methods

- **Screed Application:** Applied using a machine with auto-catalyzation³, primarily for longitudinal line work and Audio Tactile Pavement Marking (ATPM). The material generally contains intermixed glass beads to enhance night visibility and durability.
- **Spray Application:** Applied using a high-pressure spray machine with auto-catalyzation, making it ideal for highway markings. This method enables fast application with a thin, uniform finish, and the material may include intermixed glass beads and anti-skid materials depending on project requirements.

³ Auto-catalyzation refers to the self-accelerated chemical reaction that occurs when the two components of cold-applied thermoplastic (CAT) paint—the resin (base) and the hardener (activator)—are mixed. This reaction causes the material to cure and harden without the need for external heat, making it ideal for fast and efficient road marking applications.

- **Extruded Application:** Uses a machine extrusion process with auto-catalyzation to apply thicker, high-build markings, mainly for highway lines and ATPM. The extruded material often includes intermixed glass beads and anti-skid additives to ensure enhanced durability and visibility.
- **Structured Application:** Applied using specialized machines to create textured patterns for enhanced skid resistance, visibility, and wet-weather performance. This method includes agglomerates, multi-dots, checkerboard patterns, or dotted lines, which improve retro-reflectivity and durability while maintaining a solid-line appearance from a distance.

7.3.2.3. Materials

The cold-applied paint material shall be homogeneously composed of binder, pigment, extenders, and other additives as required for the formulation.

Composition

The pigments and extenders shall be uniformly dispersed in the binder medium dissolved in organic solvents. The material shall be free from skin, dirt, and foreign objects and shall comply with the requirements indicated in Table 7.3-3.

Table 7.3-3: Proportions of constituents or paint (percentage by weight).

Component	White	Yellow
Binder	25.0 min.	18.0 min.
Titanium Dioxide (Rutile)	20.0 min.	—
Calcium Carbonate and Inert Fillers	16.0 min.	29.0 min.
Yellow Pigments	—	14.0 min.

Note: Amount of yellow pigment, calcium carbonate, and inert fillers shall be at the option of the manufacturer, provided all other requirements of this Specification are met.

Properties

Non-Volatile Matter: The non-volatile content by weight shall be at least 65%, as determined by ASTM D1644.

Density/Specific Gravity: The liquid paint's density shall be a minimum of 1.3 gm/ml, measured in accordance with ASTM D1475.

Appearance

Drying Time: The no-pick-up time of the paint, tested in accordance with ASTM D711, shall not exceed 20 minutes at a wet film thickness of 350 microns. The paint must be ready to withstand traffic within 40 minutes when the ambient temperature is above 24°C.

Application Temperature: The paint should not be applied if the road surface temperature exceeds 40°C.

7.3.2.4. Properties of Dried Paint Film

Resistance to Wear: When tested with a sand abrasion tester in accordance with ASTM D968, a 75-micron thick unbeaded dry film must require more than 65 liters of sand for complete removal.

Elongation: The unbeaded dry film shall pass the test in accordance with ASTM D1737 (*Standard Test Method for Elongation of Attached Organic Coatings with Cylindrical Mandrel Apparatus*). The paint film should withstand bending over a cylindrical mandrel of specified diameter without exhibiting visible cracking. The smallest mandrel diameter over which the coating does not crack indicates the coating's flexibility and elongation capacity.

Water Resistance: The unbeaded dry film shall pass the test in accordance with ASTM D1647 (*Standard Test Methods for Resistance of Dried Films of Varnishes to Water and Alkali*). The dried paint film is immersed in water for a specified duration (commonly 18 hours). After immersion, the film should show no signs of deterioration, such as blistering, wrinkling, or loss of adhesion.

Skid resistance: Skid resistance for the beaded dry film shall be not less than 45 as per BS 6044.

Storage life: The material shall remain compliant with the specified requirements for one year. During this period, when stored in an airtight container, the paint must not develop a surface skin or form a hardened deposit at the bottom of the container.

Minimum thickness of the Unbeaded Cold-applied Paint Coat: The wet unbeaded coat of paint shall have a minimum thickness of 400 microns, while the dry unbeaded coat shall not be less than 200 microns.

Table 7.3-4: Retro-reflective properties for cold-applied paint.

<i>The minimum coefficient of retro-reflection as per British Standards BS EN 1436: 1998 shall be as under:</i>	
For white paint (Beaded)	– 300 mcd/m ² /lux on application
For yellow paint (Beaded)	– 200 mcd/m ² /lux on application

<i>The minimum luminous coefficient as per British Standards BS EN 1436:1998 shall be as under</i>	
For white paint (Unbeaded)	– 100 mcd/m ² /lux on application
For yellow paint (Unbeaded)	– 80 mcd/m ² /lux on application

Marking

Each container of cold-applied paint must be clearly and permanently labeled with the following details:

- a. Product name and trade/patent mark
- b. Batch number
- c. Manufacturing date (Month and Year)
- d. Color specification (White or Yellow)
- e. Net weight

Sampling and testing

The cold-applied reflective road marking paint shall be sampled and tested in compliance with relevant ASTM or BS test methods. The contractor shall provide the Engineer with a certified test report from the manufacturer, detailing the following results:

- a) No pick-up time, tested in accordance with ASTM D711.
- b) Wear resistance, evaluated as per ASTM D4060 or ASTM D 968, conducted by an approved laboratory.
- c) A Material Safety Data Sheet (MSDS) shall be obtained from the manufacturer and maintained with the paint materials for reference.

7.3.2.5. Retro-reflective Glass Beads

General:

Reflection is achieved by pneumatically dispersing glass beads onto the wet paint surface, ensuring they are securely embedded once the paint dries. The glass beads must be transparent, colorless, and free from impurities such as milkiness, dark particles, or excessive air inclusions. They shall comply with the specified requirements outlined below.

Specific requirements

a. Gradation: The glass beads shall meet the gradation requirements as per No. 4 of BS: 6088 as given in Table 7.3-4. An equivalent gradation, as shown in Table 7.3-2 as per AASTHO M 247, can also be used.

Table 7.3-4: Gradation requirements for glass beads for cold-applied paint (BS: 6088).

Sieve Size	Percentage Retained
250 microns	0-10
150 microns	80-100
< 150 microns	0-20

b. Roundness: The glass beads shall have a minimum of 70 per cent true Spheres.

c. Refractive Index: The glass beads shall have a minimum refractive Index of 1.50.

d. Crushing Resistance: Retained 0.425-mm (No. 40) sieve 133 N (30lbs.) minimum.

e. Moisture Resistance: The glass beads must be moisture-resistant during storage, ensuring they do not clump or form clusters. They should remain loose and free-flowing, allowing smooth dispensing from application equipment.

g. Flotation: When tested in accordance with M247-81(described below), a minimum of 90 percent of the beads shall float in xylene.

Sampling and testing

Sampling Method: The selection of samples shall be conducted randomly at a ratio of 45 kg (100 lbs.) per 4535 kg (10,000 lbs.) of material shipped. The sample shall be taken in full bags and, upon arrival, reduced to approximately 1 kg using a sample splitter for testing purposes.

Testing Requirements and Standards (as per AASTHO M 247-81):

The following properties shall be tested in accordance with the specified standards:

- Gradation: As per ASTM D1214.
- Roundness: As per ASTM D1155.
- Crushing Resistance: As per ASTM D1213.
- Refractive Index Measurement: Conducted using the liquid immersion method (Becke Line Method or an equivalent technique) at a temperature range of $25 \pm 5^{\circ}\text{C}$ ($77 \pm 9^{\circ}\text{F}$).
- Free-Flow Test: A 100-gram sample of glass beads is evenly distributed in a 100-mm diameter glass dish. This dish is placed inside a 250-mm desiccator, which contains a sulfuric acid-water solution (specific gravity: 1.10) up to 25 mm below the top of the desiccator plate. The desiccator is sealed and left undisturbed for four hours at a temperature between 20°C and 29°C . Afterward, the sample is removed, transferred to a pan, and examined for the presence of clumps or clusters. The beads are then poured into a dry glass funnel (featuring a 100-mm stem and 6-mm orifice). If necessary, a light tap on the funnel may be applied to

initiate flow. The glass beads must be free from lumps or clusters and should flow smoothly through the funnel without obstruction.

- Flotation Test: Approximately 1 gram of beads is weighed with an accuracy of 0.005 g and evenly distributed in a clean, standard 100-mm glass Petri dish, which has been pre-weighed to the nearest 0.0005 g. A slight vibration is applied to the dish to achieve a near-monolayer distribution of beads. C.P. grade xylene is introduced gradually at 10–15 mL per minute from a burette until 30 mL has been dispensed. Floating beads are carefully extracted by suction using a constricted delivery tube connected to a receiving flask. Excess liquid is removed without displacing additional beads. The dish is subsequently dried in an oven at $110 \pm 5^{\circ}\text{C}$ before being weighed again to determine the percentage of floating beads.

The Contractor shall furnish to the Engineer a copy of certified test reports from the manufacturer of glass beads obtained from a reputed laboratory showing results of all tests specified herein and shall certify that the material meets all requirements of these Specifications. However, if so required, these tests may be carried out as directed by the Engineer.

Packaging & Marking

Glass beads shall be supplied in 1-kg (or lbs.) quantities, as specified by the purchaser, and packaged in moisture-resistant bags to ensure protection against humidity. The packaging must be designed to maintain the integrity of the beads, keeping them dry and undamaged during storage and transportation. Each package must be clearly labeled with the following details:

- Manufacturer's name and address
- Shipping location
- Trademark or brand name
- The phrase "Glass Beads"
- Specification number
- Net weight in kilograms (kg) or pounds (lbs.)
- Lot or batch number
- Month and year of manufacture

7.3.2.6. Application

Marking shall be carried out using mechanical equipment, and where machine application is not feasible, approved manual methods may be used with prior authorization from the Engineer. The Contractor shall regulate traffic flow during painting operations to minimize disruptions while ensuring the safety of workers.

Cold-applied paint shall be applied onto asphalt or cement concrete surfaces using a brush or road marking/spray equipment designed to distribute the paint evenly. Glass beads, at a rate of a minimum

of 300 grams per square meter, shall be pneumatically dispersed onto the wet paint, ensuring they are firmly embedded upon drying.

The pavement temperature during application shall not exceed 40°C, and all surfaces must be thoroughly cleaned of dust, dirt, grease, oil, and other contaminants before paint application.

The material, when used for traffic stripes, must allow for direct renewal by overlaying a new layer over an existing marking. The new layer shall bond seamlessly with the old line without causing splitting or separation.

Cold-applied paint shall be applied in intermittent or continuous lines with a uniform, unbeaded dry film thickness of at least 200 microns, unless otherwise specified. For arrows, letters, or symbols, the paint may be applied manually. In addition to the initial 300 grams per square meter of glass beads, an additional 300 grams per square meter of beads conforming to specifications shall be uniformly sprayed in a monolayer onto the wet paint immediately after spraying.

The final markings shall have smooth, well-defined edges, be parallel to the alignment of the carriageway, and have a uniform surface, free from streaks or irregularities.

7.3.2.7. Preparation and Placing of Road Markings

The cold-applied reflective road marking paint must be thoroughly stirred to achieve a homogeneous mixture with the manufacturer-recommended thinner. It shall then be placed into the machine at the consistency level specified by the equipment manufacturer, ensuring proper application using appropriate viscometers. The thinner must not exceed the recommended amount to prevent bleeding or performance issues.

Properties of Finished Road Marking

- a. The striping shall maintain a non-slip surface when wet.
- b. The markings must remain firmly adhered to the pavement.
- c. Once applied and fully dried, the stripe shall resist deformation and discoloration under traffic and road temperatures up to 60°C.
- d. The markings shall withstand exposure to sodium chloride, calcium chloride, and oil drippings from passing vehicles without deterioration.
- e. The stripe or marking must retain its original dimensions and position, with sufficient cold ductility to accommodate road surface movements without cracking or chipping.

7.3.2.8. Luminance Testing on Site

Field luminance testing of thermoplastic road markings shall be conducted using a retro-reflectometer compliant with EN 1436 and ASTM E1710 to measure both nighttime retro-reflectivity (RL) and daytime visibility (Qd) and shall pass the requirements stipulated in this Specification. The device shall provide high-precision luminance readings within a measuring range of 0 - 4000 $\text{mcd}\cdot\text{m}^{-2}\cdot\text{lx}^{-1}$ (RL) and 0 - 400 $\text{mcd}\cdot\text{m}^{-2}\cdot\text{lx}^{-1}$ (Qd), ensuring compliance with visibility standards. Testing shall be performed on dry and clean surfaces, with measurements taken at regular intervals to assess uniformity and compliance with specified reflectivity thresholds. The equipment shall feature GPS integration for geolocation tracking, a built-in printer for on-site result documentation, and data export capabilities for detailed reporting and analysis. Measurements shall be taken in accordance with manufacturer guidelines to ensure repeatability and accuracy, with any deviations from required reflectivity levels promptly addressed.

7.3.2.9. Reuse of Reflective Material

At the end of each workday, any remaining material in the heater or laying apparatus should be removed as much as possible. The recovered material may be reused, provided that the maximum heating temperature has not been exceeded and that the total duration in a molten state remains within the specified limits.

7.3.2.10. Defective Materials or Workmanship

Defective materials or markings that have been improperly applied, do not meet specified dimensions, or are placed in the wrong location must be removed. The road surface shall be restored, and the markings must be reapplied correctly, all at the Contractor's expense and to the Engineer's satisfaction.

7.3.2.11. Protection of Traffic

The Contractor shall take necessary measures to protect pedestrians, vehicles, and nearby traffic from potential damage or staining caused by construction equipment, tools, materials, or paint splashes. Throughout the work, the Contractor must install and maintain appropriate warning signs and signals to ensure safe traffic movement.

Additionally, the Contractor is fully responsible for safeguarding newly completed work until it has fully hardened and can withstand traffic without damage. Any damaged markings or surfaces must be replaced or repaired at the Contractor's expense and responsibility.

7.3.3. Luminous Road Marking

7.3.3.1. Composition and Material Properties

- Luminous Pigments: Shall incorporate strontium aluminate (SrAl_2O_4)-based phosphorescent pigments with high afterglow performance, ensuring long-lasting luminance in low-light conditions (ISO 17398:2004).
- Binder: Acrylic, polyurethane, or epoxy resins must be used to provide strong adhesion and durability. The binder must be compatible with luminous pigments and prevent degradation over time.
- Glass Beads: Must be integrated to enhance retro-reflectivity, conforming to AASTHO M247-81/ BS EN 1423:2012 standards.
- UV Stabilizers: To ensure resistance to photodegradation, UV-resistant additives must be included.
- Fillers: High-quality calcium carbonate or silica-based fillers shall be used to improve abrasion resistance and durability.

7.3.3.2. Performance Requirements

- Luminance (Afterglow Performance):
 - Luminance shall meet or exceed ISO 17398:2004 phosphorescent classification, with an afterglow performance of:
 - $\geq 100 \text{ mcd/m}^2$ at 10 minutes
 - $\geq 20 \text{ mcd/m}^2$ at 60 minutes after light excitation.
 - Testing shall be conducted under controlled conditions using a standard light source D65⁴ for excitation.
- Durability: The paint shall maintain luminous and structural properties for at least 12 months under standard environmental conditions.
- Skid Resistance: The dry film shall achieve a minimum PTV (Pendulum Test Value) of 45 (indicating good slip resistance) as per BS 7976-2:2002+A1:2013 standards.
- Weather Resistance: Must withstand UV radiation, moisture, and temperature variations without significant loss of luminance or adhesion.
- Adhesion: Paint must adhere strongly to asphalt and concrete surfaces, conforming to the ISO 2409 cross-cut adhesion test.

⁴ D65 is a standardized light source defined by the International Commission on Illumination (CIE). It represents a correlated color temperature (CCT) of approximately 6500K and is meant to simulate average daylight conditions.

7.3.3.3. Application Guidelines

Surface Preparation

- Ensure the road surface is at least one month old before application.
- The surface must be clean, dry, and free from dust, oil, grease, or pollutants. If necessary, wash the surface and let it dry completely.
- For best results, apply a white undercoat paint before the luminous paint to amplify the phosphorescent effect.
- The white undercoat should be applied at 400 g/m² and allowed to dry for at least 30 minutes before applying the luminous paint.

Equipment Preparation

- Use an airless spray machine, a pneumatic spray gun, or a hand-held brush/roller for application.
- If spraying, ensure that the equipment is clean and free of previous coatings. Clean with appropriate solvent before and after use.
- If required, homogenize the luminous paint thoroughly before application to ensure even pigment distribution.

Paint Application

- If necessary, dilute the paint to achieve the desired viscosity for optimal application.
- Apply one coat of luminous road marking paint at a dosage of 900 g/m², following manufacturer recommendations.
- Ensure uniform application with clear and sharp edges. Use tape or stencils to maintain precision for lines and symbols.
- If applying multiple layers, allow each coat to dry fully before applying the next.

Drying and Protection

- Allow the luminous paint to dry for at least 45 minutes before exposure to traffic.
- Drying time may vary based on environmental factors such as humidity and temperature.
- Protect the newly painted surface from traffic and adverse weather conditions during the drying period.

Post-Application Maintenance

- After application, clean tools and spray equipment with an appropriate solvent such as acetone thinner.

- Perform regular inspections and maintenance to ensure the continued luminance and durability of the markings.

7.3.3.4. Testing and Compliance

- Luminance Testing: Shall comply with ASTM E2073-10 (Standard Test Method for Photometric Measurement of Fluorescent Coatings) and ISO 17398:2004.
- Skid Resistance Test: Conducted as per BS 7976-2:2002+A1:2013.
- Adhesion Testing: Cross-cut adhesion test in accordance with ISO 2409.
- Weather Resistance: Must comply with ISO 4892-2 (Xenon-arc exposure test) for accelerated weathering performance.
- Water Resistance: Evaluated as per ISO 2812-2 (Immersion Test) to ensure no degradation under prolonged exposure to moisture.

Luminance testing on site, re-use of material, defective materials or workmanship, and protection of traffic criteria shall be followed as described before for cold-applied reflective road marking.

7.3.4. Performed Thermoplastic Tape

7.3.4.1. Composition and Properties

- Material Composition:
 - The tape shall consist of a homogeneous mixture of resins, pigments, fillers, antiskid agents, and retro-reflective glass beads for consistent performance.
 - It shall comply with BS EN 1871:2000 for material classification and physical properties.
 - Lead-free and cadmium-free formulations must be used, with organic pigments ensuring superior color-fastness.
- Glass Beads:
 - The material shall contain a minimum of 30% glass beads by weight, ensuring compliance with AASTHO M247-81/ BS EN 1423:2012 standards.
 - Additional drop-on glass beads can be applied during heating for enhanced reflectivity in non-white colors.
- Anti-Skid Additives (Optional):
 - For increased skid resistance, an anti-slip additive can be included instead of reflective glass beads.
 - Skid-resistant thermoplastic rolls may be applied to horizontal surfaces such as steel bridge decks, manhole covers, drainage grates, or other iron/steel elements integrated into the pavement surface, to ensure adequate skid resistance.

7.3.4.2. Performance Requirements

- Softening Point:
 - The material shall have an initial softening point of $\geq 95^{\circ}\text{C}$ (Table 7, Class SP3 of BS EN 1871) to ensure stability under high-temperature conditions.
 - After heat stability testing, the softening point should not decrease by more than 10°C .
- Skid Resistance:
 - The skid resistance (SRT value) shall be ≥ 55 , complying with BS EN 1436 (Table 7, Class S3).
 - Anti-slip thermoplastic materials with integrated anti-skid aggregates shall be used where additional grip is required.
- Retro-reflectivity:
 - Provide an initial retro-reflectivity value of $\geq 300 \text{ mcd/m}^2/\text{lx}$, ensuring high nighttime visibility.
 - Retro-reflectivity shall be maintained throughout the product's lifespan, subject to correct application.
- Durability:
 - The material must withstand traffic wear, UV exposure, and environmental conditions, complying with BS EN 1824 (Road trials for durability).
 - It must be resistant to water, oil, petrol, salt, and adverse weathering from rain.

7.3.4.3. Application Guidelines

1. Surface Preparation:

- Ensure the pavement surface is clean, dry, and free from dust, oil, or contaminants.
- Tack coat primer is required for:
 - Concrete surfaces
 - Old or polished asphalt
 - Previously dirty surfaces
- New asphalt must cure for at least 6 - 8 weeks before application.

2. Application Method:

- Position the preformed thermoplastic tape at the desired location with the glass bead side facing upwards.
- Apply heat uniformly using a Thermoplastic Gas Torch (not a plumber's torch) until the material softens and bonds securely to the pavement.
- If the temperature is below 10°C , warm the road surface first before application.
- If the surface is wet, dry it with the gas torch before installation.

3. Cooling Time and Curing:

- The material shall cool and set within 2 minutes at 20°C, after which it can withstand traffic.
- Full curing shall be achieved within 10 minutes, allowing for rapid return to service.

4. Storage Requirements:

- Thermoplastic tapes must be stored at a minimum temperature of 10°C to prevent brittleness.

Luminance testing on site, re-use of material, defective materials or workmanship, and protection of traffic criteria shall be followed as described before for cold-applied reflective road marking.

7.3.5. Concrete Primer

The Concrete Primer is a synthetic resin-based colorless liquid designed to enhance adhesion between thermoplastic road marking materials and concrete or asphalt surfaces. It penetrates effectively, ensuring strong bonding and durability for road marking applications.

Physical and Chemical Properties

Table 7.3-5: Required properties of concrete primer.

Properties	Specification
Flash Point	10°C
Solids by Volume	30 ± 2%
Coverage	0.125 L/m ² (112.5 g/m ²)
Wet Film Thickness	3.04 mils (76 microns)
Dry Film Thickness	0.92 mils (23 microns)
Drying Time (Surface Dry)	10 min at 20°C, 7 min at 30°C
Painting Interval (Minimum)	15 min at 20°C, 10 min at 30°C

Note: The specific formulation, drying times, painting interval, and other requirements may vary from manufacturer to manufacturer. However, all products shall meet the minimum performance requirements mentioned in the technical datasheet of the manufacturer, necessary for effective adhesion and durability in road marking applications.

Can be applied using a brush, roller, or conventional spray. Before applying the primer, the surface must be clean and dry, free from wax, oil, grease, and dust. Application must not show significant formation of bubble or greasy residue formation/ oil or wax-like deposits (that may happen due to improper solvent evaporation or poor-quality solvent), leading to poor adhesion or adhesion failure. Prepared manually or mechanically to remove contaminants. The surface must be allowed to dry completely for at least 10 minutes before applying the thermoplastic road marking material. Compatible with thermoplastic road marking materials and suitable for both concrete and asphalt substrates.

7.3.6. Measurement

Road markings shall be measured based on the actual painted area in square meters, excluding any gaps or intervals specified in the Engineering drawings or directed by the Engineer. The measurement shall cover the full application of the specified road marking materials, including hot melt thermoplastic, cold-applied reflective road markings, luminous paints, and preformed thermoplastic tapes. The measured area shall encompass complete preparation of surfaces, application of primer where required, the thickness and uniformity of applied markings, and incorporation of retro-reflective glass beads and anti-skid materials as specified. The measurement shall also include the removal of existing thermoplastic markings, cold-applied reflective markings, luminous road markings, or preformed thermoplastic tapes as necessary for the proper application of the new works.

Directional arrows, lettering, symbols, and similar markings shall be measured separately by the actual area in square meters (m²), calculated based on the smallest rectangle that fully encloses each marking, unless explicitly detailed otherwise in the contract documents. The measured area shall include all necessary removal of existing road marking applications, surface preparation, layout accuracy, material application, bead embedding, and finishing.

Concrete primer used specifically to enhance the adhesion between road marking materials and pavement surfaces shall be measured separately in square meters, based on the actual area primed as per the Engineering drawings or as directed by the Engineer. This measurement shall include removal of existing road marking applications, surface cleaning, primer application, drying time, and any necessary preparatory treatments.

The measurement shall fully account for all labor, materials, equipment, transportation, storage, testing, quality assurance activities, traffic management, protection of freshly applied markings until adequately cured, removal and proper disposal of waste or excess materials, and all other incidental works necessary to complete the marking application as specified and approved by the Engineer.

7.3.7. Payment

The work measured as specified shall be paid under the respective contract unit rates per square meter or per number, as applicable, for each road marking type. The unit rates shall constitute full compensation for supplying, preparing, and applying the marking material (thermoplastic, cold-applied paint, luminous paint, or preformed tape), including primers, surface preparation, application of glass beads, protective measures during curing, trial applications if required, tools, labor, equipment, transportation, incidentals, testing, and correction of defective work. The rate shall also include all materials conforming to specification requirements and maintenance of markings during the defect liability period to the satisfaction of the Engineer.

Pay items shall be:

Pay Items	Description	Unit
7.3.1	Hot Thermoplastic Road Markings	Sq. meter
7.3.2	Cold-applied Reflective Road Markings	Sq. meter
7.3.3	Hot Thermoplastic Road Markings for directional arrows and lettering	Sq. meter
7.3.4	Cold Applied Reflective Road Markings for directional arrows and lettering	Sq. meter
7.3.5	Luminous Road Marking Paints	Sq. meter
7.3.6	Performed Thermoplastic Tape	Sq. meter
7.3.7	Concrete primer	Sq. meter

7.4. Audio Tactile Pavement Markings (ATPM)

7.4.1. General

Audio-tactile pavement markings (ATPM) can be used for edge line, center line/dividing lines, or wide central line treatments. The scope of work includes the installation of audio-tactile pavement markings as per the description of this Specification and guidelines explained in RHD Road Safety Engineering Manual 2024 or Engineering drawings and instructions provided by the Engineer.

7.4.2. Materials

Thermoplastic: The thermoplastic material shall comply with the provisions outlined in Clause 7.3.1 of these Specifications.

Glass Beads: Glass beads shall conform to the specifications outlined in Clause 7.3.1. The selection of samples shall be conducted randomly at a ratio of 45 kg (100 lbs.) per 4535 kg (10,000 lbs.) of material shipped. The sample shall be taken in full bags and, upon arrival, reduced to approximately 1 kg using a sample splitter for testing purposes.

Equipment

The equipment for applying audible and vibratory pavement markings shall be capable of:

- Providing continuous, uniform heating of the striping material to temperatures exceeding 200°C, ensuring thorough mixing and agitation in the reservoir to achieve a homogeneous mixture without segregation.
- Maintaining the striping material in a plastic state throughout all mixing and conveying components, including the line dispensing device, until application.
- Producing a consistent pattern of transverse bars positioned at regular, predetermined intervals.

- traveling at a uniform speed, both uphill and downhill, to ensure consistent application of the striping material. It should adeptly follow straight lines and navigate standard curves accurately.
- Automatically applying glass beads to the surface of the completed stripe using dispensers attached to the striping machine. These dispensers must release the glass beads immediately behind the installed line and be equipped with an automatic cut-off synchronized with the thermoplastic material cut-off, ensuring uniform application with 50 to 60 percent embedment.
- Including a specialized kettle designed for uniform heating and melting of the striping material. The kettle should have an automatic temperature control device and a material thermometer to ensure precise temperature management and prevent overheating or scorching of the thermoplastic material.

7.4.3. Application

Prior to applying traffic stripes and markings, any substances that may hinder proper adhesion must be removed using a method approved by the Engineer.

For applications on concrete surfaces, a primer, sealer, or surface preparation adhesive, as recommended by the manufacturer, must be used before applying the traffic stripes. Additionally, longitudinal lines should be positioned at least 50 mm away from construction joints in concrete pavement.

If audible bars are provided in conjunction with the marking lines, traffic stripes or markings shall only be applied to a dry surface, ensuring that the ambient air and pavement surface temperature is at least 10°C and rising for asphalt surfaces, and at least 16°C and rising for concrete surfaces. A similar condition shall be applied if audible bars are applied in separation.

When overlaying audible bars on existing markings, no more than 50 mm at either end and no more than 25 mm on either side of the existing line should remain visible.

Dimensions of Transverse Audible Bars: Typical dimensions of audio-tactile ribs are given in Table 7.4-1.

Table 7.4-1: Typical dimensions of audible bars of ATPM.

Dimension	Edge Lines	Dividing Lines
Width of raised ribs	150–200 mm	100–150 mm
Length of raised ribs (longitudinal direction)	60 mm ± 10 mm	
Height of raised ribs (proud of pavement surface)	10 mm ± 2 mm	

Spacing of raised ribs (longitudinal direction) 250 mm $\pm$ 50
mm

Note: Dimensions are in accordance with AS 1742.2:2022 – Manual of uniform traffic control devices – Part 2: Traffic control devices for general use (Standards Australia, 2022).

The preferred minimum cross-section width of a sealed roadway for the use of ATPM is 9.0 m, comprising two 3.65 m lanes and two 1.0 m sealed shoulders. However, ATPM can be used where the total pavement width is an absolute minimum of 7.0 m (the edge line should have a clear distance of 150 mm to the edge of the bitumen).

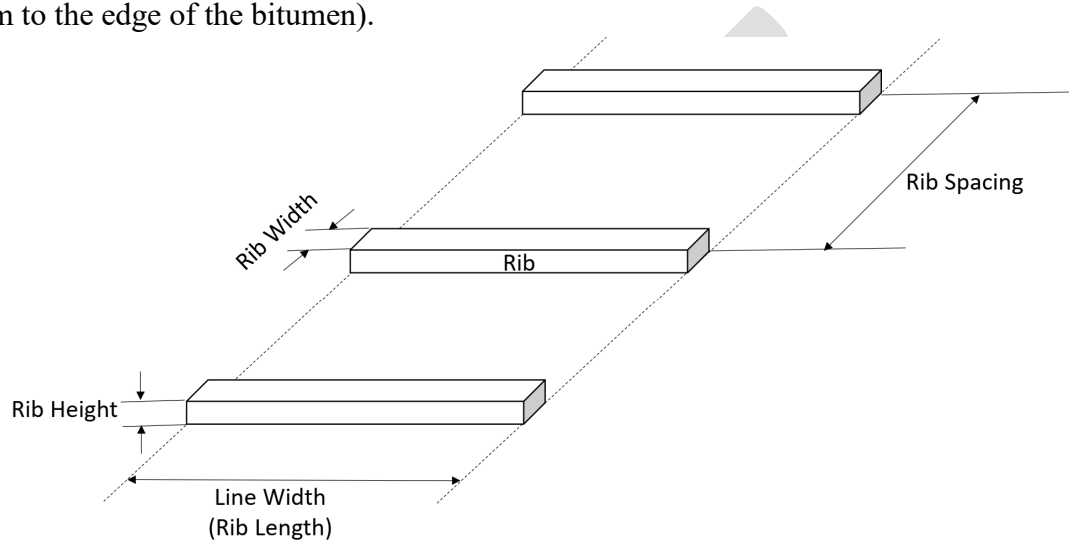


Figure 7.4-1: Example of thermoplastic audio-tactile edge/center line.

Note: Dimensions in accordance with Austroads (2020) *Guide to traffic management. Part 10: Transport control – Types of devices* (3rd ed.). Austroads.

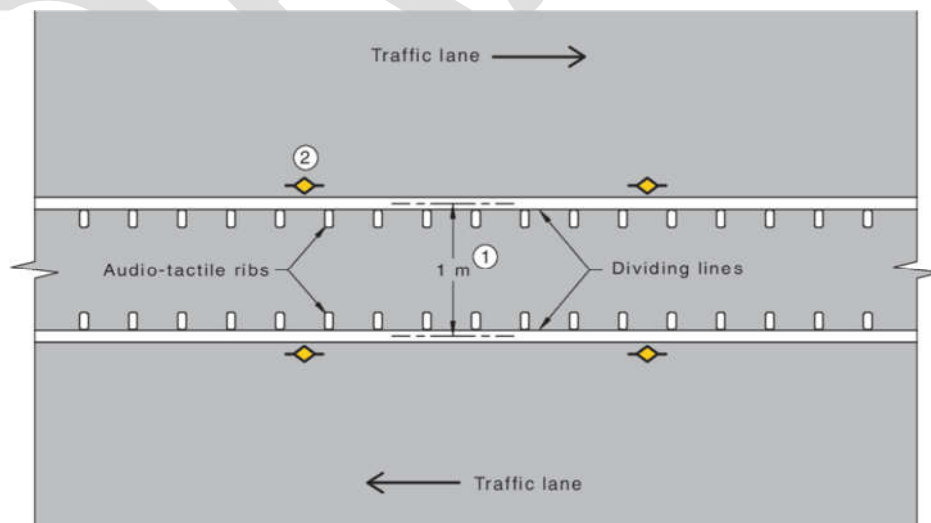


Figure 7.4-2: Example of thermoplastic audio-tactile wide central line.

Source: (Standards Australia, 2022)

Retro-reflectivity:

White $\geq 300 \text{ mcd/1x.m}^2$

Yellow $\geq 250 \text{ mcd/1x m}^2$.

Glass beads: Glass beads shall be applied to all pavement markings. The manufacturer shall determine whether a single or double application is required and specify the appropriate drop rates for each application.

Protection of newly applied audio-tactile markings: Newly applied pavement markings shall be protected from traffic until they have dried sufficiently. Vehicles shall not be allowed to cross or come into contact with the markings until they are fully set. Any markings damaged due to traffic or other causes shall be removed and reapplied.

7.4.4. Measurement

Audio-tactile pavement markings shall be measured in linear meters of completed and accepted work, categorized by type (edge line, dividing line, or wide central lane). all cleaning and preparing of surfaces, furnishing of all materials, primer or adhesive (if required), application of thermoplastic compound, glass bead dropping, curing, protection of traffic, furnishing of all tools, machines, and equipment, and all incidentals necessary to complete the work.

7.4.5. Payment

Payment shall be made at the contract unit rate per linear meter for each type of audio-tactile marking, which shall constitute full compensation for all work including surface cleaning, materials, heating and mixing, application of markings and glass beads, use of regular/specialized equipment, curing, protection of markings, traffic safety measures, and replacement of any defective work within the observation period. Final payment shall be made upon satisfactory completion and correction of deficiencies.

Pay items shall be:

Pay Items	Description	Unit
7.4.1	Audio Tactile Pavement Markings	Lin. meter
7.4.2	Wide Central Lane Marking	Lin. meter

7.5. Raised Pavement Markers (RPM)**7.5.1. General**

This section covers the supply, installation, and performance requirements of Raised Pavement Markers (RPMs), including both retro-reflective and solar-powered types, used to supplement road markings for enhanced night-time visibility, lane delineation, and tactile feedback. RPMs are applied along centerlines, lane lines, edge lines, medians, and painted traffic islands, especially on high-speed corridors, rural roads, and locations with limited or no street lighting.

Raised Pavement Markers function by reflecting headlamp light back toward the driver's line of sight, ensuring improved visibility under both dry and wet conditions. In addition to visual guidance, they provide audible and tactile warnings when traversed by vehicle wheels, thereby contributing to lane discipline and crash prevention.

RPMs shall be durable, weather-resistant, and capable of withstanding impact loads from traffic. They shall be designed for ease of installation and maintenance, and may be surface-mounted, embedded, or anchored using shear pins, depending on the application. The color and placement of RPMs shall follow functional guidelines to enhance roadway safety and driver awareness.

All materials, geometry, retro-reflective performance, and installation methods shall conform to the relevant provisions of AASHTO, EN, or other internationally recognized standards, as well as the requirements specified in the RHD Road Safety Engineering Manual 2024, the approved engineering drawings, and any instructions issued by the Engineer, to ensure consistency, durability, and overall performance across the RHD road network.

7.5.2 Retro-reflective Raised Pavement Markers (RRPM)

Raised pavement markers should conform to EN1463 (EU) or equivalent standard. Markers may be depressible or non-depressible. They may be embedded, surface-bonded with adhesives, or anchored by shear pins. The maximum height above the pavement surface should be 20mm to 25mm for depressible markers.

RPMs can be unidirectional and bidirectional. Unidirectional RPMs reflect light in one direction, guiding traffic on one-way roads, ramps, and edge marking and lane marking. Bi-directional RPMs reflect light in both directions, improving visibility on two-way roads, centerlines, and medians.

A good quality road surface is required for installation. Markers should not be provided over pedestrian crossings and at stop lines, as they could be slippery.

Color and Spacing

Generally, where they augment painted lines, reflective markers are used to ensure adequate alignment and lane delineation at night and during inclement weather. RRPMs are used in various colors as follows, in accordance with the UK Traffic Signs Manual (2018):

- White: Marks traffic lanes, the center of the carriageway, and painted traffic islands.
- Red: Indicates studs that should not be crossed, primarily marking the left-hand edge of the carriageway, except where traffic is allowed to cross.
- Yellow: Highlights dividing lines, barrier lines, painted traffic islands, and the right-hand edge of one-way carriageways, particularly on dual carriageways, to prevent vehicles from encroaching into the central reservation.
- Green: To indicate a length of the edge of the carriageway/continuity line which may be crossed. Defines exit and entry points at grade-separated junctions, guiding vehicles through deceleration and acceleration lanes to ensure smooth transitions.

Table 7.5-1: Color and spacing of road studs.

Type of road marking	Color shown by the stud	Spacing (m)	
		Urban	Rural
Centre line/dividing line/barrier line	Yellow	6	9
Lane line	White	6	9
Warning Line	White	6	9
Edge Line	Red	12	18

Material

The plastic casing of road pavement markers (RPMs)/road studs shall be manufactured using ASA (Acrylic-Styrene-Acrylonitrile), HIPS (High-Impact Polystyrene), ABS (Acrylonitrile Butadiene Styrene), or any other suitable material approved by the Engineer.

The reflective panels shall be composed of multiple lenses featuring single or dual prismatic cubes designed to achieve total internal reflection of incident light. These lenses shall be molded from methyl methacrylate or similar, meeting the requirements of ASTM D788 or an equivalent standard.

Design

As per ASTM D4280-04, the specifications for road markers are as follows:

- The height of the marker shall not exceed 20.3 mm.

- The width of the marker shall not exceed 130 mm.
- The angle between the marker's reflective face and its base shall not exceed 45°.

Retro-reflectivity

According to ASTM D4280-04, the Coefficient of Luminous Intensity (CIL) for each reflector on a road stud should meet or exceed the values specified in Table 7.5-2 of the standard.
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The CIL values are measured at a 0.2° observation angle with entrance angle components of 0° and ±20°. The minimum required CIL values, expressed in millicandelas per lux (mcd/lx), are as follows:

Table 7.5-2: Minimum coefficient of luminous Intensity (CIL) for reflective road studs.

Entrance Angle Component (β_2)	Observation Angle (α)	White	Yellow	Red	Green	Blue
0°	0.2°	279	167	70	93	26
+20° / -20°	0.2°	112	67	28	37	10

Tests

The physical performance requirements for road markers are as follows:

- **Flexural Strength:** Markers designed for installation on flexible, asphaltic concrete pavements must endure a load of 8,914 N without breaking.
- **Compressive Strength:** Each marker must withstand a 2,727 kg (6,000 lbs) load without breaking or experiencing significant deformation. Deformation exceeding 3.3 mm (0.13 in.) is considered significant.
- **Lens Impact Resistance:** The lens face must not exhibit more than two radial cracks exceeding 6.4 mm (0.25 in.) in length. Additionally, no cracks should extend to the edge of the abrasion-resistant area, and delamination must not occur.
- **Temperature Cycling Durability:** Markers subjected to temperature fluctuations must remain free from cracking or delamination.

Note: The methods for each of the tests are outlined in ASTM D4280-04.

The luminance performance criteria for road markers are outlined as follows:

- The Coefficient of Luminous Intensity (C.I.L.) shall be measured in accordance with ASTM E809, Standard Practice for Measuring Photometric Characteristics, or as specified in BS 873-Part 4: 1973.

Under testing conditions, a road stud will not be considered non-compliant with photometric requirements if its measured C.I.L. at any given test position falls below the values specified in Table 7.5-1, provided that:

- a. The measured value is at least 80% of the required minimum.
- b. The average of the left and right measurements for the specified angle meets or exceeds the required minimum value.

7.5.3. Solar-powered Raised Pavement Markers (Solar Studs)

Material: Solar Road studs shall be manufactured from aluminum alloy and polycarbonate materials, ensuring durability and resistance to extreme weather conditions. They shall be strong enough to withstand a compressive load of 2,727 kg (6,000 lbs) without breakage or significant deformation, as per ASTM D4280. Significant deformation is defined as exceeding 3.3 mm (0.13 in).

Color: The color of the solar studs may be white, red, yellow, green, or a combination thereof, as specified by the Engineer. The studs must also be water-resistant to prevent ingress and ensure long-term performance in varying environmental conditions.

Luminance: Shall conform to the criteria for retro-reflective raised pavement markers described in section 7.5.2.

Dimensions: The dimensions of solar studs typically measure 100 mm x 100 mm x 20 mm, providing a compact and robust design suitable for various road applications.

LED Visibility: Equipped with high-brightness LEDs, these studs shall offer a visibility distance of over 500 meters, enhancing road safety by providing clear guidance to drivers even in adverse weather conditions.

Flashing Rate: The LEDs shall not operate in flashing modes.

Operational Temperature Range: Designed to withstand various environmental conditions, these studs shall function optimally within a temperature range of -20°C to +60°C, ensuring reliable performance across diverse climates.

Lifespan: With robust construction and efficient energy management, the operational lifespan of these studs should be typically over 30,000 hours, translating to several years of maintenance-free service.

Please note that these specifications for visibility distance, operating temperature, and lifespan may vary depending on the design and quality of the manufacturer, and the acceptance shall be based on contemporary technological advancement and at the discretion of the Engineer.

7.5.4. Fixing

The head profile of the road stud shall be smooth to ensure minimal impact on traffic and shall not have any sharp edges that could pose a hazard. The reflective surfaces must be free from crevices or ledges where dirt and debris could accumulate, ensuring consistent reflectivity and performance.

The dimensions of the road studs shall conform to the following requirements:

- The height shall be no less than 10 mm and shall not exceed 20 mm.
- The width shall not exceed 130 mm.
- The base of the marker must have a flatness tolerance of 1.3 mm. If the base is textured or patterned, the outermost surfaces shall not deviate more than 1.3 mm from a flat plane.
- The base of the marker must not have any glossy finishes or substances that could interfere with its adhesion to the road surface.
- Each road stud shall be legibly marked with the manufacturer's name, trademark, or another form of identification for quality assurance and traceability.

7.5.5. Placement

The reflective marker shall be securely affixed to the road surface using manufacturer-recommended adhesives and installation procedures. To prevent potential road hazards, nails shall not be used for fastening the markers.

Regardless of the adhesive type, markers shall not be installed on surfaces that are damp or wet. On new asphalt concrete pavements, installation shall only take place after the surface has been open to traffic for at least 14 hours.

Before application, the designated bonding area on the road must be clean and free of contaminants such as dirt, curing compounds, grease, oil, moisture, loose material, paint, or any other substance that could compromise adhesion.

The adhesive shall be applied uniformly on the clean pavement surface or the underside of the marker in a quantity sufficient to ensure complete contact coverage. No voids should be present, and a slight excess of adhesive should be visible after the marker is gently pressed into place.

For epoxy-based installations, any excess adhesive around the marker's edges, on the pavement, or on the exposed surfaces of the marker must be immediately removed to ensure a clean and effective installation.

7.5.6. Performance and Durability

The Contractor shall provide a two-year warranty ensuring the satisfactory field performance of the installed reflective road markers, including compliance with the stipulated retro-reflectance standards of the reflective panels.

Additionally, the Contractor shall guarantee the in-field durability of the completed road markers for a period of two years from the date of installation. This warranty shall cover both the performance and the fixing of the markers.

If any markers become displaced, damaged, worn out, or fail to maintain the required reflectivity as per the specified standards, the Contractor shall be responsible for replacing all such markers within 15 days of receiving notification from the Engineer, at no additional cost.

7.5.7. Measurement

Raised pavement markers, including both retro-reflective and solar-powered types, shall be measured by the number of units installed, accepted, and performing as specified. Measurement shall include supply, surface preparation, adhesive application, placement, cleaning, setting, and any reapplication due to displacement or failure during the warranty period. Only properly fixed and operational markers, meeting the reflectivity and durability requirements, shall be considered for payment.

7.5.8. Payment

Payment shall be made at the contract unit rate per marker and shall constitute full compensation for furnishing all materials (including reflectors, adhesives, and components), labor, tools, transport, equipment, surface cleaning, installation, testing, documentation, and warranty obligations. The payment also covers any required replacements during the defect liability period, as instructed by the Engineer.

Pay items shall be:

Pay Items	Description	Unit
7.5.1	Retro-reflective Raised Pavement Markers	Number
7.5.2	Solar-powered Raised Pavement Markers	Number

7.6. Removal & Treatment of Existing Thermoplastic Pavement Markings

7.6.1 General

This work involves the removal of existing thermoplastic pavement markings from bituminous and concrete pavements to facilitate the application of new markings. The removal process must be executed using approved methods that prevent damage to the underlying pavement and ensure the safety of road users. All removal activities shall be subject to the approval of the Engineer.

7.6.2. Removal Techniques

The removal of existing thermoplastic pavement markings shall be conducted using methods suitable for bituminous or concrete surfaces. The technique shall be selected based on pavement type, marking thickness, surface condition, environmental factors, and operational feasibility. All removal processes shall be demonstrated through a trial section and approved by the Engineer.

1. Mechanical methods

Mechanical Grinding / Milling / Flailing

Removal is achieved using rotating abrasive heads or toothed spindles/drums to scrape or cut thermoplastic markings from the surface. These methods may result in surface scarring, particularly on bituminous pavements, and are generally suitable for spot removals or small-area work.

Orbital Abrasive Discs

Often used for precise grinding, it is less aggressive but slower.

Drum-Type Milling Machines

Equipped with stacked disk cutters for continuous removal, useful on wide linear markings.

2. Blasting

High-Pressure Water Blasting (Hydro-blasting)

A truck-mounted system using water jets at pressures up to 30,000 psi (210 MPa) combined with vacuum suction to remove thermoplastic markings. This method is effective on both asphalt and concrete surfaces and minimizes surface scarring. However, it must be operated above freezing temperatures to avoid system malfunction and pavement damage.

Sand Blasting

Compressed air is used to propel sand aggregates against the pavement to abrade markings. While effective, this method can polish or scar the surface, especially on bituminous pavements, and may leave ghost markings. Requires a separate system for debris collection.

Hydro-Sand Blasting (Obsolete)

Formerly used at pressures up to 10,000 psi (69 MPa) with combined water and abrasive materials. This method has largely been replaced by high-pressure water blasting.

3. Thermal Removal

Hot Compressed Air (HCA)

Utilizes combustion chambers to generate heated gas streams up to 1,320°C (2,400°F), directed at the marking for softening and scraping. Best suited for thick applications or built-up markings. Should not be used in high ambient temperatures or on soft asphalt due to the risk of pavement damage.

Excess-Oxygen Flame Removal

A high-temperature flame ($>2,480^{\circ}\text{C}$ / $4,500^{\circ}\text{F}$) generated by propane-oxygen mixtures. Effective, but must be carefully applied to avoid asphalt deformation.

4. Chemical and Other Methods

Chemical Softening Agents

Solvents or chemical compounds are applied to weaken thermoplastic markings, followed by pressure washing. Limited to small-scale applications or indoor facilities due to environmental restrictions.

Masking

When removal is not feasible, thermoplastic markings may be obscured using masking materials that match the road surface color. This is a temporary solution, typically used in junction areas.

Temporary Tapes / Preformed Marking Films

Removable tapes may be applied over old markings as an interim measure.

7.6.3 Application

a) Depth and width control

- Removal depth: The removal process should not exceed a depth of 1 mm to prevent compromising the pavement integrity.
- Removal width: The width of the area from which markings are removed shall not exceed the original marking width by more than 1 cm on either side.

b) Junction areas

In junction areas where complete removal is impractical, existing thermoplastic markings may be covered with a bituminous resealing layer during leveling operations, subject to the Engineer's approval.

c) Surface cleaning

After removal, the pavement surface must be cleaned of all residues and debris using appropriate methods such as compressed air or vacuum systems. The surface should be free of contaminants to ensure proper adhesion of new markings.

7.6.4. Measurement and Payment

Shall be covered in pay items for road markings, viz, retro-reflective thermoplastic paint, cold-applied reflective road markings, luminous road markings, or performed thermoplastic tapes.

7.7. Traffic Control and Safety Devices in Construction Zones/School Zones/Temporary Work Zones

7.7.1. General

Traffic control and safety devices used in construction zones/school zones/temporary work zones include traffic signs, delineators (such as traffic cones, drums, barricades, vertical posts, longitudinal barriers, tapes), as well as other equipment like flagmen, reflective jackets, and headgear. Construction zone traffic signs shall conform to the standards outlined in the RHD Road Safety Engineering Manual 2024 or as directed by the Engineer. Materials and other requirements for traffic signs shall adhere to Clause 7.1 of these specifications.

This section includes the application and specification of construction zone/school zone traffic control and safety devices other than the relevant traffic signs as per the guidelines explained in RHD Road Safety Engineering Manual 2024 or Engineering drawings and instructions provided by the Engineer.

7.7.2. Traffic Cones

7.7.2.1. Description

Traffic cones, commonly referred to as safety cones, road cones, construction cones, or witch's hats, are portable, conically shaped markers widely used for temporary traffic control. These devices are primarily deployed on roadways to guide and alert drivers of ongoing/temporary work zones, lane diversions, channelization, or restricted access areas. They are also used for crowd control and traffic management at public events, construction sites, and during emergency or short-duration maintenance activities.

Traffic cones used in Bangladesh shall conform to specifications derived from the Manual on Uniform Traffic Control Devices (MUTCD) 2023 and the RHD Road Safety Engineering Manual 2024, as detailed in subsequent clauses.

Color Requirements:

Traffic cones shall be fluorescent red-orange in color for the cone body, providing high daytime visibility and conforming to MUTCD color specifications. Retro-reflective bands or stripes shall be white, complying with ASTM D 4956 Type IV or higher for reflective performance. The use of any other body or reflective colors is not permitted unless explicitly approved by the Engineer for specific applications (e.g., blue for law enforcement zones, green for environmental areas), and such usage shall be in accordance with relevant RHD and MUTCD provisions.

Design and application

Cones intended for daytime use on low-speed roads shall have a minimum height of 450 mm. When deployed on highways, expressways, high-traffic-volume roads, or at night on any roadway, or when enhanced visibility is necessary, cones shall have a minimum height of 700 mm.

For nighttime applications, cones must be retro-reflectorized to enhance visibility. Cones with a height between 700 mm and 900 mm shall have a 150 mm wide white retro-reflective band positioned 75 mm to 100 mm from the top, with an additional 100 mm wide white band located approximately 50 mm below the first band. Cones exceeding 900 mm in height shall feature horizontal, circumferential, alternating orange and white retro-reflective stripes that are 100 mm to 150 mm wide. Each cone must

have at least two orange and two white stripes, with the top stripe always being orange. Any non-retro-reflective gaps between these stripes shall not exceed 75 mm in width. Design features supporting the application shall be:

- Traffic cones must be adequately weighted to prevent tipping due to wind pressure or the turbulence from passing vehicles.
- Stability may be enhanced by nesting cones (doubling) or using ballast in fillable bases.
- Sandbags or weighted rings may be applied over the base; however, ballast should be limited to the minimum required to avoid creating additional hazards.
- Cones must remain upright and effective in all expected environmental conditions, including rain and wind gusts, without posing a risk to road users.
- Provision of holes for fixing plastic chains or caution tape enables perimeter control and improved delineation.

Material

Traffic cones shall be manufactured from 100% virgin polyvinyl chloride (PVC) or thermoplastic elastomer (TPE), ensuring high flexibility, durability, and impact resistance. The material shall exhibit the following properties:

- UV Resistance: UV-stabilized to prevent fading and degradation under prolonged sunlight exposure (ASTM D 4329).
- Color Integrity: Fluorescent red-orange pigment shall be integrated into the base material to ensure long-term visibility and color retention.
- Impact Performance: Material shall demonstrate flexibility and resilience, with no cracking or permanent deformation under impact, including at low temperatures (ASTM D 746).
- Reflective Sheeting Compatibility: Surface must allow firm adhesion of reflective materials conforming to ASTM D 4956 Type IV or higher.
- Non-Toxic Composition: Material shall be lead-free and compliant with environmental safety standards; recyclable content may be used in base components.
- Surface Finish: Smooth external surface for visibility and cleaning; lightly textured interior to prevent cones from sticking when stacked.

7.7.2.2. Measurement [Only if retained as RHD properties]

Measurement for traffic cones shall be made on a per-unit basis, representing each individual cone that is supplied, deployed, maintained, and, where necessary, replaced at the site during the execution of the works. The quantity shall include all cones required for initial installation, as well as those used for temporary or supplementary deployment, repositioning, or reinstallation as instructed by the Engineer. Measurement shall also cover cones replaced due to damage, loss, or deterioration over the contract

period. No separate measurement shall be made for cones that are moved or reused within the same worksite, unless specifically directed by the Engineer.

7.7.2.3. Payment [Only if retained as RHD properties]

Payment shall be deemed to include the cost of supply, transportation, on-site deployment, routine maintenance, repositioning, and final removal of cones, as well as replacement of damaged or missing cones throughout the duration of the project. It shall also cover all associated labor, equipment, tools, and incidental materials necessary to ensure the cones remain in serviceable condition and in compliance with the requirements of Clauses 7.7.2.1 through 7.7.2.3.

Pay item shall be:

Pay Item	Description	Unit of Measurement
7.7.2.1	Traffic cones	Number

7.7.3. Drums

7.7.3.1. Description

Traffic drums are used as channelizing devices in work zones to guide road users safely. They are designed to be highly visible, portable, and capable of withstanding various environmental conditions while minimizing damage to vehicles upon impact. Drums should adhere to the following specifications, as adapted from MUTCD 2023:

Dimensions and Design:

- Height and Diameter: The minimum height and width of a traffic drum shall be 900 mm and 450 mm, respectively, irrespective of orientation, with a closed-top design to prevent the accumulation of debris.
- Material: Constructed from lightweight, flexible, and deformable materials such as Linear Low-Density Polyethylene (LLDP) or similar plastics to minimize vehicle damage upon impact. The use of steel drums shall not be permitted due to safety concerns.
- Color: Drums are typically bright yellow to ensure high visibility in various weather conditions.
- Portability: Designed for easy relocation within temporary traffic control projects, drums should remain stable over prolonged periods yet be light enough for manual handling.

Reflective Markings:

- Each drum should feature horizontal, circumferential, alternating orange and white retro-reflective stripes. The stripes should be 100 to 150 mm wide, with a minimum of two

yellow/orange and two white stripes per drum. Any non-reflective spaces between these stripes should not exceed 50 mm in width.

Structural Features:

- Drums should have closed tops to prevent the accumulation of debris, ensuring they remain visible and functional.
- While drums should be stable, they should not be filled with sand, water, or other materials that could pose hazards to motorists, pedestrians, or workers upon impact. In regions prone to freezing temperatures, drums should have drainage holes at the base to prevent water accumulation and potential freezing hazards.
- Ballast should not be placed on top of the drum to avoid creating additional hazards.

7.7.3.2. Measurement [Only if retained as RHD properties]

Measurement for traffic drums shall be made on a unit basis, representing each individual drum that is supplied, deployed, maintained, and, where necessary, replaced throughout the duration of the works. The measurement shall include drums installed at the start of the project, as well as those relocated, repositioned, or newly placed as directed by the Engineer during the execution of temporary traffic control or work zone operations. No separate measurement shall be made for drums that are temporarily removed and reinstalled within the same work zone or for the purpose of minor site adjustments unless explicitly instructed.

7.7.3.3. Payment [Only if retained as RHD properties]

Payment shall constitute full compensation for the supply, transport, placement, maintenance, and final removal of the traffic drums. It shall also include any incidental costs related to labor, tools, ballast installation, rubber bases, and all associated accessories necessary to ensure that the drums remain upright, visible, and serviceable. The cost shall also include replacement of damaged, lost, or stolen drums during the project period, unless damage or loss is demonstrably caused by force majeure and exempted by the Engineer.

Pay item shall be:

Pay Item	Description	Unit
7.7.3.1	Drums	Number

7.7.4. Barricades

7.7.4.1. Description

Class

A barricade is a portable or permanent device having from one to three rails with appropriate markings and is used to control road users by closing, restricting, or delineating all or a portion of the right-of-way. Barricades must remain stable under adverse weather conditions but should be designed in a way that minimizes damage if struck by a vehicle. The following specifications for Barricades are adapted from MUTC 2023.

Barricades are classified into three types:

- Type I: Single rail barricade for general-purpose lane delineation.
- Type II: Double rail barricade with increased retro-reflectivity for highways and high-speed roads.
- Type III: Large, multi-rail barricade for full road closures and high-impact zones.

Material

Type I and Type II barricades: The barricades shall have a minimum rail/panel length of 600 mm with a rail width between 200 mm and 300 mm. The rails must feature alternating orange and white stripes, each 150 mm wide, sloping at a 45° angle in the direction of traffic. The support structure should be A-frame or another foldable design to facilitate easy transportation and stacking. To enhance stability, ballasting with sandbags may be used, particularly in high-wind conditions or on highways. Sandbags should be positioned at the lower parts of the frame or stays to provide sufficient weight, but must not be placed on top of any striped rail. The use of heavy objects such as rocks or concrete chunks for ballasting is strictly prohibited to prevent additional hazards.

Type-III barricade: Type-III barricades are designed for permanent installations and can be constructed from wood, metal, or other suitable materials. They typically consist of three or more horizontal panels, each measuring at least 1200 mm in length (with additional length based on site requirements) and 300 mm in width. The panels must be painted with alternating orange and white stripes, 150 mm wide, angled at 45° in the direction of traffic flow. These barricades should be securely mounted on at least two vertical supports made of the same material for structural stability. In high-wind areas or highway locations, sandbags may be used for ballasting but must be placed at the lower sections of the frame or stays, ensuring they do not rest on top of any striped rails. The use of heavy objects like rocks or concrete chunks for ballasting is strictly prohibited to prevent additional safety hazards.

Application

Type I and Type II barricades are utilized in temporary traffic control zones where traffic flow is maintained. They may be deployed individually or in groups to indicate specific conditions or arranged in a sequence to channelize traffic. Type I barricades are commonly used on conventional roads, urban streets, and arterial routes, while Type II barricades, which offer greater retro-reflective visibility, are better suited for highways, expressways, and other high-speed roadways.

Type III barricades are primarily used for road closures and may extend completely across the roadway or from curb to curb. If access for authorized vehicles or equipment is required, a designated individual should be responsible for ensuring that the barricade is properly closed at the end of each workday.

In cases where a highway is legally closed but access for local traffic is permitted, the Type III barricade should not block the entire roadway. Instead, a clearly visible sign indicating local traffic access should be installed.

Additionally, signage can be mounted on barricades, particularly fixed ones, to enhance visibility and provide guidance to road users. Common signs include ROAD CLOSED, DETOUR, ARROW, and large arrow warning signs, which should be positioned effectively on or above the barricade to maximize visibility. For detailed application and

7.7.4.2. Measurement [Only if retained as RHD properties]

Measurement shall be made in linear meters, based on the cumulative length of all horizontal rails provided across all installed barricades. The total length shall reflect the physical rail length used, taking into account both the number of rails per barricade and the length of each rail, as per the approved design. For example, a Type I barricade with a single 1.2-meter rail shall be measured as 1.2 meters; a Type II barricade with two 1.2-meter rails shall be measured as 2.4 meters; and a Type III barricade with three 1.5-meter rails shall be measured as 4.5 meters.

The work under this item shall include the furnishing, installation, maintenance, repositioning, and removal of barricades as specified in the Engineering drawings and as directed by the Engineer. Each measured unit shall include all components necessary for a complete and functional barricade, including vertical supports, rails or panels with compliant retro-reflective striping, base structures, ballasting materials where required, and any incidental fittings. Maintenance, repositioning, and realignment of barricades in accordance with shifting traffic management phases shall be considered incidental to the work and included in the unit rate. Barricades damaged due to negligence or poor maintenance shall be replaced or repaired by the Contractor at no additional cost to the Employer.

7.7.4.3. Payment [Only if retained as RHD properties]

Payment shall include the cost of supply, transportation, on-site deployment, and routine maintenance of barricades. It shall constitute full compensation for furnishing all labor, materials, equipment, and final removal of barricades (if necessary) in accordance with the specifications and to the satisfaction of the Engineer.

Pay items shall be:

Pay Items	Description	Unit
7.7.4.1	Barricades (Type I/II)	Lin. meter

7.7.4.2	Barricades (Type III)	Lin. meter

7.7.5. Flagger and STOP/GO Portable Boards

7.7.5.1. Description

Deployment of Flaggers

Flaggers shall be stationed in locations where:

- Traffic lanes are intermittently obstructed by workers or equipment without protective barriers.
- A single lane is used for two-way traffic flow, requiring controlled alternation of vehicle movement.
- Traffic guidance, warning, or control is deemed necessary to enhance safety and ensure smooth traffic flow.

Flagger Qualifications and Equipment

Flaggers must be attentive, responsible, and capable of efficiently performing their duties. They shall be equipped with appropriate hand signaling tools, including flags and sign paddles, to manage traffic effectively.

Safety Gear and Visibility

Flaggers shall wear high-visibility safety apparel, including helmets, gloves, protective footwear, and reflective garments to enhance their visibility. When working at night or in low-light conditions, flaggers must wear reflective clothing that ensures they remain conspicuous to approaching motorists.

Flag Specifications

Flags used for signaling shall be at least 450 mm by 450 mm in size, made of durable red fabric, and securely attached to a staff measuring approximately 1 meter in length to ensure effective visibility and handling.

STOP/GO (Thamoon and Chaloon) Portable Sign Paddles

Portable STOP/GO sign paddles shall have a minimum diameter of 600 mm and be equipped with a rigid handle measuring at least 1.5 meters in length for ease of use.

- The STOP sign shall have a red background with white lettering, and its shape must be octagonal, ensuring compliance with the Road Safety Engineering Manual 2024.

- The SLOW sign shall feature a green background with black lettering, designed to provide clear visibility and effective communication to road users.

7.7.5.2. Measurement

Measurement shall be made per unit, where one unit consists of a qualified flagman equipped with required high-visibility safety gear and a compliant STOP/GO portable sign paddle. The number of units shall be counted for each eight (08) hour shift of deployment, as approved by the Engineer.

7.7.5.3. Payment

Payment shall be full compensation for providing trained flagmen, STOP/GO sign paddles, safety apparel, signaling tools, deployment, supervision, and all associated incidentals necessary for effective manual traffic control.

Pay item shall be:

Pay Item	Description	Unit of Measurement
7.7.5.1	Flagger	Number

7.7.6. Personal Protection Equipment for Workers

7.7.6.1. General Requirements

This section covers the requirements for Personal Protective Equipment (PPE) for all workers exposed to moving roadway traffic or construction equipment within work zones. The intent is to minimize occupational hazards and enhance worker safety through the proper use of high-visibility safety apparel and protective gear.

All workers shall wear PPE that complies with relevant safety standards to ensure adequate protection, comfort, and durability under varying work conditions. PPE shall include, but is not limited to, high-visibility garments, helmets, gloves, protective footwear, and eye protection, as appropriate to the task and site environment.

All PPE must be regularly inspected, maintained, and cleaned to ensure continued effectiveness. Damaged, worn, or ineffective gear shall be replaced immediately. The Contractor shall ensure that all personnel are properly trained in the selection, fitting, use, and maintenance of PPE in accordance with safety regulations and manufacturer guidelines.

7.7.6.2. High-Visibility Safety Apparel/Reflective Clothing

Material and Construction

High-visibility apparel shall be made from fluorescent polycotton fabric (typically 80% polyester/20% cotton) or 100% polyester with a minimum fabric weight of 105 g/m², providing resistance to dirt, grease, and mechanical stress. The inner lining should incorporate a black honeycomb polyester structure to reduce perspiration and enhance wearer comfort, particularly during extended use.

Garments must be lightweight and breathable, with a maximum weight of 660g per vest or equivalent garment, allowing for extended wear in various weather conditions. The design shall ensure quick and safe donning, particularly over a body harness, and facilitate unrestricted movement for the worker. Donning shall be simple, with garment designs specifically suited to fit over fall-arrest or safety harnesses without belt interference.

Each garment shall include at least two double front pockets, equipped with flap closures secured by press studs, to support worker convenience and utility in the field. Closure mechanisms shall include either a zipper or hook-and-loop fasteners to ensure a secure and adjustable fit.

Colors and Reflective System

The outer garment shall be available in fluorescent yellow, orange, or red/lime, providing visibility in both daylight and low-light environments. The apparel must feature horizontal and vertical retro-reflective bands, 50 mm wide, encircling the torso and arms, and extending to trouser legs or sleeves for full 360-degree visibility.

The reflective system shall ensure effective retro-reflectivity during both dry and wet conditions. Reflective strips must remain functional after repeated exposure to environmental stress and laundering.

Types and Classes

High-visibility clothing may include vests, jackets, T-shirts, pants, coveralls, and raincoats, selected based on weather, job function, and site conditions. The performance class of the garment shall be suited to the risk level of the work zone and must comply with Class 2 or Class 3 requirements of ISO 20471:2013.

Garments classified as Class 1 shall not be permitted for use in any roadway work zone under this contract. The table below is provided for reference only:

- Class 1 – Minimum visibility, for low-risk, low-speed areas (e.g., sidewalks, parking lots).

- Class 2 – Intermediate visibility for urban road construction or medium-speed zones.
- Class 3 – Maximum visibility for high-speed roads, expressways, or nighttime work.

Table 7.7.6-1: Dimensional requirements for different classes of reflective clothing.

Class	Min. Background Material	Min. Retro-reflective Material	Notes
Class 1	0.14 m ²	0.10 m ²	Not for nighttime without additional lighting
Class 2	0.50 m ²	0.13 m ²	Standard for road work zones
Class 3	0.80 m ²	0.20 m ²	For high-speed or nighttime operations

A minimum of (50 ± 10) % of the required visible background material shall be present on the front side of the garment. Garments shall be laid flat for measurement, including the torso, sleeves, and legs.

Testing Requirements for High-Visibility Apparel

All high-visibility garments must undergo strict performance testing to verify compliance with ISO 20471:

- Color fastness testing: The fluorescent material must retain its color after prolonged exposure to UV light.
- Retro-reflective performance testing: The reflective material must maintain minimum retro-reflectivity values under wet and dry conditions.
- Abrasion resistance: The material should withstand wear and tear in rugged environments.
- Tensile strength: Ensures durability and resilience against mechanical stress.
- Wash cycle testing: Ensures visibility is retained after repeated washing and industrial laundering.

7.7.6.3. Safety Headgear

Workers must be equipped with safety helmets (headgear) that meet EN 397 requirements for shock absorption, resistance to penetration, flame resistance, and chin strap anchorage. The helmets must be lightweight, comfortable, and durable, providing protection against falling objects and impact-related injuries.

Material and Design Features

Helmets shall be manufactured from high-grade polyethylene or equivalent impact-resistant material, designed for durability, comfort, and lightweight performance in field operations. The shell must retain deformability in case of impact and resist odors, heat, and physical wear. Helmets must be suitable for both high and ground-level operations, ensuring versatility across work environments.

Only short visor caps are acceptable for this application to enhance upward visibility. Each helmet shall be equipped with a 4-point textile headband and an adjustable fitting system, either rack and pinion or slider type, to ensure a secure and customizable fit for different head sizes. A removable comfort band must be provided to improve wearability during long shifts. Helmets shall provide protection against accidental contact with electrical conductors, reducing the risk of electrical shock during operations in electrically active environments.

Ventilation features may be excluded to maintain shell integrity and protection in high-risk environments. Helmets shall be washable, odor-resistant, and have a minimum usable life of three (3) years. Each helmet shall be provided in white/yellow color unless otherwise specified in the Bill of Quantities.

7.7.6.4. Safety Footwear

All workers shall wear safety footwear when engaged in road construction zones where there is exposure to impact, puncture, electrical, and slip hazards. All safety boots shall conform to EN ISO 20345 standards for personal protective footwear and provide steel or composite toe protection with an energy absorption capacity of at least 200 joules.

The boots shall be constructed from water-repellent full-grain leather with a thickness of 2.5 to 2.7 mm, and equipped with a leather inner lining for enhanced comfort and durability. A quilted fold-down collar is required for ankle protection and ergonomic fit. The sole shall offer hydrocarbon resistance, anti-slip properties, and waterproofing. The midsole shall be anti-puncture leather with a dielectric rubber layer resistant up to step voltages of 20 kV, with an insole dielectric resistance of up to 10 kV under dry conditions.

The footwear shall include rustproof eyelets, a protective foam layer over the steel toecap, and a dielectric sole thickness of at least 2.5 mm. Designs must ensure adequate flexibility and comfort, supporting extended use in varied working conditions without restricting mobility.

7.7.6.5. Protective Gloves

Gloves shall be worn to protect against cuts, abrasions, and mechanical hazards associated with construction activities. The gloves must be impact-resistant, cut-resistant, and abrasion-resistant, offering protection against mechanical risks as well as electrical hazards and environmental exposure. Gloves shall comply with the relevant international standards, including EN 388 for mechanical protection and EN 420 for general glove requirements. For electrical applications, gloves must meet the performance requirements of IEC 60903 or equivalent.

Mechanical Protection Gloves (General Construction Use)

Gloves intended for general construction work shall be seamless-knit, with a polyurethane (PU)-coated palm for enhanced grip and abrasion resistance. The glove liner shall be made of high-density polyethylene (HDPE) blended with fibers such as polyamide and wrapped glass fibers, providing superior cut and tear resistance.

- Cut Resistance Level: 5
- Abrasion Resistance Level: 4
- Tear Resistance Level: 4
- Puncture Resistance Level: 3
- Slicing Resistance Level: 5
- Wrist Design: Elasticated knitted wrist for a secure and snug fit
- Back Design: Open back for ventilation
- Grip and Dexterity: PU-coated palms ensure secure grip and high flexibility for tool handling

These gloves shall be lightweight, comfortable, and suitable for tasks involving tools, sharp materials, or debris handling.

High-Voltage Rubber Insulating Gloves (Electrical Safety Use)

For electrical operations, workers shall be equipped with long composite rubber insulating gloves, designed for high-voltage live-line work.

- Type: Bicolor chlorinated long gloves with black interior and red exterior
- Length: 800 mm
- Protection Class: Class 3 (up to 26,500V AC operating voltage)
- Proof Test Voltage: 30,000V AC
- Thickness: Less than 4.2 mm
- Material Category: F (mechanical protection), R (acid, oil, ozone resistance), C (low temperature resistance)
- Additional Accessories: Each glove set shall include a keeping bag and rubber cleaning spray (200 ml)

7.7.6.6. Respiratory Protection

Workers exposed to dust, fumes, or airborne particles in the work zone shall wear respiratory protection masks that comply with EN 136 (Respiratory Protective Devices – Full Face Masks) and EN 166 B (Eye Protection – High-speed Particle Impact) or equivalent. Masks shall be compatible with NIOSH-approved N95 filters or higher-rated particulate filters, and shall include a twin-cartridge air delivery system for efficient breathing support.

Design and Material Specifications

- **Material:** Constructed from thermoplastic rubber and polycarbonate, offering lightweight comfort, chemical resistance, and long-term durability.
- **Filter Compatibility:** Must support integrated seal-check functionality, allowing users to verify a proper face-seal before use.
- **Exhalation Valve:** Equipped with a low-resistance exhalation valve designed to minimize breathing effort and enhance user comfort.
- **Visor:** Fitted with a Class 1 optical-grade panoramic visor, made from impact-resistant polycarbonate, providing a wide field of vision and protection against high-speed airborne particles.
- **Air Delivery:** Features a twin cartridge filtration system to ensure balanced air flow and efficient particulate removal.
- **Maintenance:** Designed for easy disassembly and cleaning, enabling repeated use under proper hygiene and maintenance protocols.

7.7.6.7. Eye and Face Protection for Welding Operations

Workers engaged in welding, cutting, or related activities must use eye protection gear that complies with EN 175 for passive welding shields or EN 379 / EN 169 for auto-darkening welding filters. These shields must offer adequate protection from optical radiation, sparks, and debris, ensuring maximum safety and visibility.

7.7.6.8. Hearing Protection (Earplugs / Earmuffs)

Workers exposed to high noise levels from heavy machinery and power tools must wear earplugs or earmuffs to prevent hearing damage and long-term auditory issues. Protection should comply with EN 352 or OSHA standards, ensuring adequate noise reduction (NRR) based on workplace conditions.

7.7.6.9. Fall Protection Equipment (Harnesses, Lanyards, and Anchors)

For working at heights, workers must use full-body harnesses, shock-absorbing lanyards, and secure anchors to prevent falls. Equipment must comply with EN 361 / ANSI Z359.1 / OSHA 1926, ensuring proper load-bearing strength and durability. Regular inspections and training are essential for safe use.

7.7.6.10. Measurement [Only if retained as RHD properties]

Measurement for Personal Protective Equipment (PPE) shall be made per item supplied and accepted at the site, in accordance with the specifications and as approved by the Engineer. Each item shall be

measured as a complete, functional unit, including all necessary components, accessories, and manufacturer-supplied documentation.

Where applicable, PPE items such as safety vests, helmets, gloves, footwear, respiratory masks, welding shields, hearing protection, and fall arrest systems shall be counted individually and paid by the number of units provided. Combination units (e.g., full-face respirators with twin cartridges, or harnesses with lanyards) shall be measured as a complete set.

No separate measurement shall be made for training, inspection, or replacement of damaged PPE during the contract period; such activities shall be considered incidental to the work.

7.7.6.11. Payment [Only if retained as RHD properties]

Payment for each type of Personal Protective Equipment (PPE) supplied shall constitute full compensation for procurement, delivery, documentation, accessories, and all associated costs to ensure compliance with the specified standards. The unit rate shall also include costs for inspection, fitting, and any required replacement of defective or non-compliant items prior to acceptance.

Pay items shall be:

Pay Items	Description	Unit of Measurement
7.7.6.1		
(a)	High visibility safety apparel/Reflective clothing	Number
(b)	Safety headgear	Number
(c)	Safety footwear	Number
(d)	Protective gloves	Number
(e)	Respiratory protection	Number
(f)	Eye and face protection for welding operations	Number
(g)	Hearing protection devices	Number
(h)	Fall protection equipment (Harnesses, Lanyards, and Anchors)	Number

7.8. Conspicuity tape

7.8.1. General

Conspicuity tape is a highly reflective adhesive material used for enhancing the visibility of vehicles, barriers, road signs, and construction zones, particularly in low-light and nighttime conditions. It is designed to increase safety by improving object detection for motorists, pedestrians, and workers. The

tape shall be weather-resistant, durable, and compliant with international standards for road safety applications. Two types of conspicuity tapes are used:

1. Vehicle Conspicuity Tape: FMVSS 108 (USA)-Federal Motor Vehicle Safety Standard)/ ECE 104 (Europe)-Regulation for vehicle markings standard tapes used on trucks, trailers, buses, emergency vehicles, tankers, inspection vehicles, and large commercial vehicles to improve visibility of dynamic objects.

Requirement

Compliant with Regulation ECE104/ FMVSS 108

Adhesive Type	Pressure-sensitive, solvent-free
Construction	Flexible, Micro prismatic
Length	50 m
Performance Level	Diamond Grade
Width	50 mm

Color of marking material

Rear marking	red or yellow
Side marking	yellow or white

Installation

Installation will be done as per the manufacturer's standard guidelines or as per the instructions of the Engineer in charge.

2. Road Construction and Safety Conspicuity Tape: ASTM D4956 / EN 12899-1 standard tapes used on barriers, guardrails, traffic signs, work zone equipment, cones, and delineators to improve road safety.

Compliant with Regulation ASTM D4956 / EN 12899-1

Adhesive Type	Pressure-sensitive, solvent-free
Construction	Flexible, Micro prismatic, or glass bead retro-reflective sheeting
Performance Level	High-intensity, Diamond Grade
Width	50 mm, 100 mm (other sizes available)

Color of marking material

As per functional requirements	White, Yellow, Red, Blue, Green (as per EN 12899-1)

Installation

Installation will be done as per the manufacturer's standard guidelines or as per the instructions of the Engineer in charge.

7.8.2. Measurement [Only if retained as RHD properties]

Measurement for conspicuity tape shall be made in running meters, based on the actual length of tape applied to vehicles, barriers, guardrails, signs, or other designated surfaces, as accepted by the Engineer. Measurement shall include all types, widths, and colors specified, regardless of surface or application type.

7.8.3. Payment [Only if retained as RHD properties]

Payment shall be full compensation for furnishing materials, surface preparation, installation, labor, tools, adhesives, and all incidental works necessary to complete the item in accordance with the specifications and as directed by the Engineer.

Pay items shall be:

Pay Items	Description	Unit
7.8.1	Conspicuity tape	
(a)	Vehicle Conspicuity Tape	Lin. meter
(b)	Road Construction and Safety Conspicuity Tape	Lin. meter

7.9. Delineators

7.9.1 General

This section covers the design, supply, and installation of delineators used as roadside guidance devices to enhance driver awareness of roadway alignment, particularly under nighttime or adverse weather conditions. Delineators serve as visual aids that define the edges and alignment of the roadway, especially at horizontal and vertical curves, lane transitions, narrow structures, and other areas where alignment may be unclear or unexpected. Unlike warning signs, delineators are intended to provide continuous visual guidance and reinforcement of road geometry, contributing to improved safety and driving comfort.

Delineators are particularly effective on high-speed roads, hill roads, and rural highways, where they remain visible even when the pavement is wet, or obscured by debris. The selection of delineator type, such as alignment delineators, lane delineators, or median markers, shall be based on roadway function and site-specific conditions.

All delineator materials, geometry, color coding, mounting height, and retro-reflective performance shall conform to the RHD Road Safety Engineering Manual 2024, the approved engineering drawings, and any instructions issued by the Engineer. Additionally, materials and retro-reflective elements shall comply with relevant AASHTO, ASTM, EN, or other internationally recognized standard specifications, as referenced in this Specification, to ensure durability, visibility, and safety throughout the RHD road network.

7.9.2. Delineator Color Coding

The colors of retro-reflective delineators affixed to guideposts/supporting structures shall be assigned based on roadway type and function, as outlined in Table 7.9-1 below:

Table 7.9-1: Delineator reflector colors for left-side driving rule countries.

Road Type	Side of Carriageway	Reflector Color	Application Rule
Two-way road (undivided)	Left-hand side	Red	Posts facing oncoming vehicles on the left edge of the road.
	Right-hand side	White	Posts facing oncoming vehicles on the right edge of a two-way road.
One-way road (including divided roads)	Left-hand side	Red	Posts facing oncoming vehicles on the left edge of the carriageway.
	Right-hand side	Yellow	Posts facing oncoming vehicles on the right edge of a one-way road or median side of a divided carriageway.

Special cases:

Green: Designates perimeter of heavy vehicle rest areas or specific roadside zones, subject to relevant jurisdictional or authority guidance.

Blue: Reserved for water service points, such as fire hydrants, with installation governed by applicable local or agency-specific regulations.

7.9.3. Delineator Categories

- Alignment delineator
- Lane delineator
- Median markers

7.9.3.1. Alignment delineator

Alignment delineators serve to highlight road curves and alignment, making them particularly useful in areas with a higher risk of vehicles veering off the roadway. These include curved sections, lane reduction zones, areas where lanes merge or diverge, and locations where road geometry presents a hazard, such as near narrow bridges. Their primary function is to guide drivers by providing a clear visual indication of the road's path, helping to reduce run-off-road accidents.

To ensure visibility at night, delineators should be fitted with retro-reflective elements. These devices must be capable of reflecting light effectively under normal weather conditions, particularly at night, from a distance of 300 meters when illuminated by the high beams of a standard vehicle. They should be mounted on a crashworthy⁵ supports enhancing safety.

Design: For optimal visibility, reflectors should be positioned at least 700 mm above the road surface to prevent obstruction by vegetation. The preferred color scheme consists of white posts with black stripes, featuring a red reflective element on the left side facing traffic and a white reflective element on the right side. Detailed specifications and installation guidelines can be found in the BRTA Traffic Sign Manual (2000) and the RHD Road Safety Engineering Manual (2024).

⁵ Crashworthiness refers to the capability of roadside safety hardware or appurtenances to reduce risks to vehicle occupants during a collision. This is achieved by either decelerating the vehicle before it comes to a stop, redirecting it safely, or allowing it to proceed with minimal resistance. The effectiveness of such devices is evaluated based on nationally recognized standards, such as the 2016 edition of the *Manual for Assessing Safety Hardware (MASH)* by AASHTO.

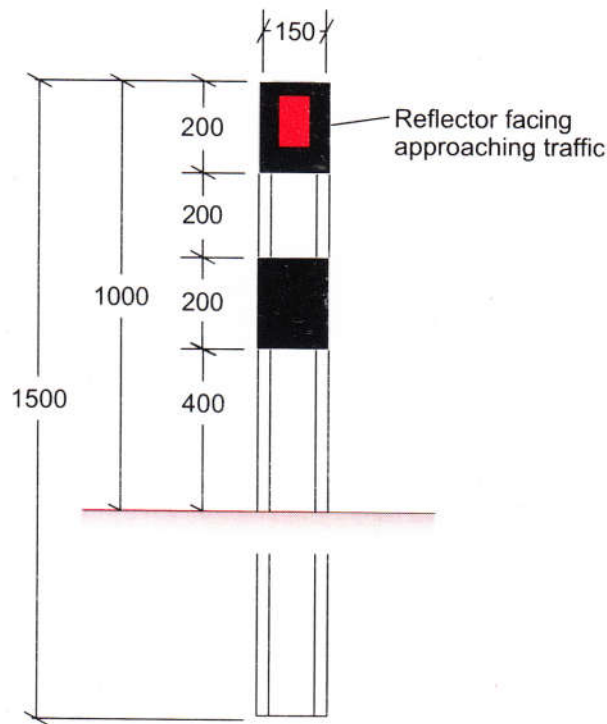


Figure 7.9-1: Typical design of alignment delineator post.

Placement: Delineators should be positioned 600 mm from the road edge to ensure drivers can consistently see at least three posts ahead when navigating hazardous sections. As a standard practice, roadway indicators should be placed at the edge of the usable shoulder. If installed at kerbed sections, they should be placed 600 mm inside the kerb face.

In hilly areas, placement may vary based on available roadway width and Right of Way (RoW); they can be mounted either on the parapet or along the edge of the earthen shoulder. The alignment of delineator posts should generally be parallel to the centerline of the road. However, near guardrails or other roadside obstacles, the positioning may be adjusted so that the delineators are either in line with or set slightly inside the inner edge of the obstruction.

Alignment delineators shall primarily be considered for horizontal curve sections and vertical curves with inadequate visibility. Spacing recommendations for horizontal curves are provided in Table 7.9-1, which serves as a guide for the appropriate placement of alignment delineators.

Table 7.9-1: Spacing of alignment delineators (ref: BRTA Traffic Sign Manual).

	Spacing (m)

Curve Radius (m)	Outside of curves	Inside of curves*
< 100	6	12
100- 199	10	20
200- 299	15	30
300- 399	20	40
400- 599	30	60
600- 799	40	60
1200- 1199	60	60
1200- 2000	90 **	90 **
> 2000 and straight	150 #	150 #

* Position to match delineator on opposite side

** Adopt 60m in areas susceptible to fog

Adopt 75m in areas susceptible to fog and 90m where low beam light is used, and adopt 90m where wire rope safety barriers are used

Alignment delineator at straight sections can be used in the following conditions:

- Road segments where visibility is frequently reduced due to mist, fog, or snowfall.
- Locations where the alignment may be unclear to drivers, such as transitions in pavement width or temporary detours.
- Sections prone to water accumulation or frequent submersion due to stormwater runoff.
- Approaches leading to narrow bridges and culverts.
- Outer edges of hill roads along valley sides.
- Entry points to major intersections.
- Critical areas such as tunnels and causeways.

For straight road segments where delineators are required, they should be installed at regular intervals of 50 to 70 meters. In such cases, they should be placed in pairs, with one positioned on each side of the road to ensure uniformity and clear visibility for drivers. In other high-risk areas, the spacing of delineators should range from 2 to 10 meters, depending on what provides the most effective guidance through the hazardous section.

7.9.3.2. Lane delineators

Lane delineators are flexible posts installed along the centerlines of undivided roads. They are also appropriate for installation over narrow traffic islands separating opposing traffic lanes, slow vehicle lanes, or parking areas. Lane delineators may be used along both straight sections and curves to deter overtaking in addition to solid line markings.

The main purposes of lane delineators are

- Deterrence of corner cutting along curves
- Deterrence of overtaking on straight sections or curves
- Prevention of wrong-way traffic
- Highlighting the presence of traffic islands



Figure 7.9-2: Typical Lane delineator post.

7.9.3.3. Median markers

Median marker should be used for improving median visibility under dark conditions. The use of median markers provides safety against collision with medians during nighttime or severe weather. Flexible median markers shall be provided with yellow retro-reflective sheeting Type XI as per ASTM D4956 on a flexible thermoplastic body, or rigid median markers shall be provided with yellow reflective panels composed of multiple lenses featuring prismatic cubes designed to achieve total internal reflection of incident light, meeting the requirements of ASTM D788 or an equivalent standard. The body or shank of the rigid median marker may be made of ASA (Acrylic-Styrene-Acrylonitrile), HIPS (High-Impact Polystyrene), ABS (Acrylonitrile Butadiene Styrene), stainless steel/ aluminum, or any other suitable material approved by the Engineer. The reflective area shall not be less than 90 cm square. Typically placed at barrier/kerb sides or on top of barrier/kerb.

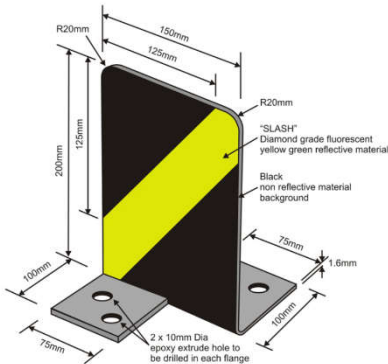


Figure 7.9-3: Different types of median marker.

7.9.4. Material

The materials used for delineators, including posts, retro-reflective elements, and mounting accessories, shall conform to the requirements of the RHD Road Safety Engineering Manual 2024, relevant engineering drawings, and any instructions issued by the Engineer. All components shall be durable, weather-resistant, and capable of withstanding mechanical impacts, UV exposure, and temperature fluctuations common in roadside environments.

7.9.4.1 Delineator Posts

(a) Flexible Posts

Flexible delineator posts shall be made of high-impact UV-stabilized thermoplastic materials such as polyurethane (PU), high-density polyethylene (HDPE), or other approved flexible polymers. Posts shall be designed to self-recover to their original upright position after repeated impacts without permanent deformation or loss of function. Typical post diameter shall be 75-100 mm with a height of 750 mm to 1200 mm above ground. Reflective sheeting shall conform to ASTM D 4956 Type XI or equivalent, with a minimum reflective area of 75 mm x 225 mm, securely bonded to the post surface.

(b) Rigid Posts:

Rigid delineator posts may be fabricated from precast concrete or composite plastic as specified. Precast concrete posts shall be cylindrical, with a minimum 150 mm diameter, and 1.5 meters in length, embedded into the ground as per design drawings. All rigid posts shall be free of sharp edges and designed to minimize injury and vehicle damage upon impact.

(c) Galvanized Steel Posts:

Steel delineator posts shall be hot-dip galvanized after fabrication in accordance with AASHTO M111 or ASTM A123. Steel shall conform to a minimum tensile strength of 345 MPa and a minimum yield strength of 250 MPa. Posts shall be flanged channel or round pipe sections of a minimum 1.67 kg/m, cut and drilled as per approved design.

7.9.4.2 Reflective Elements

Delineator units shall be equipped with either sealed prismatic reflectors or micro prismatic retro-reflective sheeting, depending on the delineator type and installation application.

(a) Reflex Reflector Units:

Reflex reflector units shall consist of hermetically⁶ sealed, prismatic lenses made of impact-resistant acrylic or polycarbonate, approximately 75 mm in diameter. These shall be housed in a durable casing, typically aluminum or UV-stabilized polymer, with embossed features or raised patterns for structural integrity. The reflector housing shall include a single grommet⁷ or recessed mounting hole for secure attachment to the delineator post or structure. These units shall be fully weatherproof, UV-resistant, and designed to maintain reflective performance over extended outdoor exposure.

⁶ Hermetically sealed means that an object is completely airtight and protected from external elements such as air, moisture, or dust. In the context of delineator units, a hermetically sealed acrylic plastic reflex reflector is one that is enclosed in a way that prevents the entry of air or water, ensuring durability and long-term performance in various weather conditions.

⁷ a ring made of rubber, metal, or plastic.

(b) Reflective Sheeting Panels:

As an alternative to reflex reflector lenses, flexible plastic delineator posts may be equipped with retro-reflective sheeting panels measuring approximately 75 mm × 225 mm. The sheeting shall conform to ASTM D4956 Type XI or an equivalent international standard, ensuring excellent visibility under both dry and wet night conditions. Reflective sheeting shall be firmly bonded or factory-applied to ensure long-term durability and prevent peeling or delamination.

7.9.4.3 Mounting Brackets

Brackets for mounting delineators on concrete barriers or structures shall be fabricated from structural aluminum (ASTM B221) or zinc-coated steel, and shall include stainless steel fasteners. Brackets shall be designed for secure installation and ease of maintenance, with no sharp edges or protrusions.

7.9.5 Construction and Installation

7.9.5.1 Installation of Delineator Posts

- Posts shall be installed vertically at the locations, offsets, and intervals specified in the drawings or as directed by the Engineer.
- Flexible and rigid posts shall be either driven, anchored, or embedded in concrete as per site conditions.
- For flexible posts, the use of anchor bases with epoxy or bolt-down systems is preferred for removability and replacement.
- Rigid or steel posts shall be installed using impact tools or manual setting without damaging the post structure. Posts damaged during installation shall be removed and replaced at the contractor's expense.

7.9.5.2 Mounting of Delineator Units

- Reflective delineator units shall be securely mounted on posts or fixed roadside structures using aluminum screw-nails, rivets, or pre-fitted mounting systems approved by the manufacturer.
- Where brackets are required (e.g., on concrete barriers or parapets), they shall be mounted using stainless steel bolts, washers, and rubber gaskets to prevent corrosion and ensure structural stability.
- Delineator units may be installed as single or double reflectors, depending on the roadway configuration. The center of the top reflector shall be mounted at a minimum height of 700 mm above the pavement surface, or as specified in the approved design.
- All delineator elements shall be properly aligned to face oncoming traffic, ensuring clear retro-reflectivity at night and during adverse weather conditions.

- In kerbed sections or along medians, delineators shall be installed 600 mm offset from the kerb face, unless otherwise instructed by the Engineer.
- If required, delineator posts may be notched or pre-drilled to accommodate the reflector unit, and installation shall ensure a flush, secure fit without any protrusions.
- On-site assembly of delineators shall follow the approved design drawings and specifications, ensuring consistency in mounting height, alignment, and visibility.

7.9.6. Performance Requirement

Pre-qualification warranty of at least 2 years for field performance shall be submitted by the Contractor for technical qualification in the tender. Two Years Warranty Certificate for Delineator for the quantity installed and a certified copy of test reports from an independent test laboratory conforming to mechanical properties shall be obtained from the Manufacturer by the Contractor and submitted to the Engineer-In-Charge.

7.9.7. Measurement

The work under this item shall be measured by the number of delineator units installed, completed, and accepted in accordance with the specifications and as shown on the approved drawings or directed by the Engineer. Each unit shall include the complete assembly comprising the delineator post (steel, concrete, rigid, or flexible), reflective element (reflector or sheeting), mounting bracket (if applicable), and all associated hardware, properly fixed at designated locations.

7.9.8. Payment

Payment for delineators shall constitute full compensation for the supply of delineator posts, reflectors or retro-reflective sheeting, mounting brackets or accessories, all labor, tools, equipment, transportation, excavation or anchoring, site cleaning, and all incidental work necessary for proper installation and performance. All payments shall also cover the warranty obligations and required compliance documentation as specified.

Pay items shall be:

Pay Items	Description	Unit
7.9.1	Delineator with Steel Posts	Number
7.9.2	Delineator with Flexible Posts (Lane delineator)	Number
7.9.3	Delineator with Rigid Posts	Number
7.9.4	Median Marker	Number

7.10. Solid Concrete Interlocking Paving Blocks Pavement on Footpath

7.10.1. General

This section of the specification outlines the technical requirements for solid concrete interlocking paving blocks, intended for use in footpaths, pedestrian walkways, medians, traffic islands, non-motorized traffic (NMT) zones, parking lots, traffic-calmed zones, and light-load bearing, pedestrian-priority at-grade surfaces. These paving units serve critical functions in enhancing pedestrian safety, surface aesthetics, and the overall durability and maintainability of roadside infrastructure. They also contribute to effective stormwater management, load distribution, and slip resistance on frequently trafficked surfaces.

The specifications provided herein are aligned with the requirements and test protocols of the following internationally recognized standards:

- ASTM C936/C936M – Standard Specification for Solid Concrete Interlocking Paving Units
- EN 1338:2003 – Concrete Paving Blocks – Requirements and Test Methods

The work under this specification shall consist of precast solid concrete interlocking paving blocks conforming to lines, levels, slopes, typical cross-sections, and locations shown in the Engineering drawings and as instructed by the Engineer, in accordance with these technical specifications. However, any additional requirements such as weight classification, enhanced compressive strength, surface texture, finish, or color shall be defined by the purchaser. It is advisable to verify the availability of such features with local manufacturers or suppliers during procurement planning.

7.10.2. Material requirements

7.10.2.1. Cementitious Materials

All cementitious components used in the production of interlocking concrete paving blocks shall comply with the relevant ASTM specifications listed below. The materials shall be free from impurities that adversely affect the performance or durability of the concrete mix.

- Ordinary Portland Cement: ASTM C150/C150M – Standard Specification for Portland Cement
- Blended Hydraulic Cements: ASTM C595/C595M – Types IS or IP
- Performance-based Hydraulic Cement: ASTM C1157/C1157M
- Hydrated Lime (Type S): ASTM C207 – For supplementary use where specified
- Fly Ash: ASTM C618 – Class F or C, subject to compatibility
- Ground Granulated Blast-Furnace Slag (GGBFS): ASTM C989/C989M
- Silica Fume: ASTM C1240 – For enhanced durability and reduced permeability

7.10.2.2. Aggregates

Aggregates used in the manufacturing of paving units shall meet the physical and durability requirements of ASTM standards. Grading compliance is not mandatory unless otherwise specified by the Engineer, but material quality and cleanliness must be ensured.

- Normal Weight Aggregates: ASTM C33/C33M – Standard Specification for Concrete Aggregates
- Lightweight Aggregates: ASTM C331/C331M – For Concrete Masonry Units

All aggregates shall be clean, durable, and free from organic matter, clay lumps, soft particles, or other deleterious substances.

7.10.2.3. Chemical Admixtures and Mixing Water

All chemical admixtures used in the concrete mix shall comply with the following ASTM standards, and shall not impair the durability, strength, or setting characteristics of the concrete:

- Air-Entraining Admixtures: ASTM C260/C260M
- Water-Reducing, Retarding, and Accelerating Admixtures: ASTM C494/C494M
- Color Pigments for Integrally Colored Concrete: ASTM C979/C979M

Water used for mixing or curing shall be clean and potable, conforming to ASTM C1602/C1602M. It must be free from deleterious substances such as oils, acids, alkalis, salts, organic matter, or other impurities that may compromise setting time, strength development, or long-term durability.

7.10.3. Physical Requirements

- a. Concrete interlocking paving blocks shall be of specified or approved size, shape, and thickness, designed to be installed manually using a single hand. The exposed face area shall not exceed 0.065 m² (101 in²), and the aspect ratio (length ÷ thickness) shall be no greater than 4:1. The minimum thickness shall be 60 mm (2.36 in.) as per ASTM C936/C936M.
- b. Units may be manufactured using normal weight, lightweight, or a combination of both aggregates in accordance with ASTM and EN specifications.
- c. At the time of delivery, paving units shall exhibit an average compressive strength of not less than 55 MPa (8000 psi), with no individual unit falling below 50 MPa (7200 psi), as required by ASTM C936/C936M.
- d. The concrete mix shall contain a minimum cementitious content of 380 kg/m³ to ensure durability and consistent strength gain.

- e. Absorption - The average water absorption of tested units shall not exceed 5% by mass, with no individual unit exceeding 7%, in line with both ASTM C936 and EN 1338, Class B.
- f. Abrasion Resistance - Units shall be tested for abrasion resistance using ASTM C418, and the average volume loss shall not exceed $15 \text{ cm}^3/50 \text{ cm}^2$, with thickness loss $\leq 3 \text{ mm}$. As per EN 1338, alternate classification may be referenced as Class 3 or higher, if relevant.
- g. Dimensional Tolerance - Length or width: Shall not deviate more than $\pm 1.6 \text{ mm}$ ($\pm 1/16 \text{ in}$) from the specified dimension. Height (thickness): Shall not vary by more than $\pm 3.2 \text{ mm}$ ($\pm 1/8 \text{ in}$), consistent with ASTM C936 and EN 1338 tolerances. of units shall not differ by more than $\pm 1.6 \text{ mm}$ ($\pm 1/16 \text{ in}$) from approved samples.
- h. Slip/Skid Resistance - Concrete paving blocks intended for pedestrian use shall exhibit adequate slip resistance when tested in accordance with ASTM E303 (British Pendulum Tester) or an equivalent method. The minimum slip/skid resistance value shall not be less than 45 USRV, in accordance with EN 1338, unless otherwise specified by the relevant national code or authority.
- i. Dimensional Tolerances: The dimensions of each interlocking concrete paving unit shall conform to specified tolerances prior to the application of any surface finishes. The measured length and width of individual units shall not deviate by more than $\pm 1.6 \text{ mm}$ ($\pm 1/16 \text{ inch}$), while the thickness shall not vary by more than $\pm 3.2 \text{ mm}$ ($\pm 1/8 \text{ inch}$) from the specified dimensions.

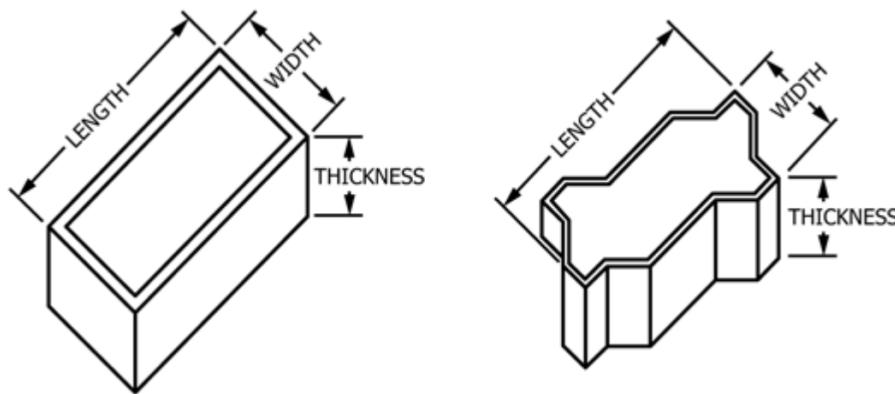


Figure 7.10-1: Length, Width, and Thickness of Concrete Paving Blocks.

- j. Spacer Nibs: A small projection on the vertical face of each paving unit, known as a spacer nib, should be provided to facilitate uniform joint spacing, typically ranging from 2 to 5 mm. These projections assist in maintaining alignment during installation, promote surface water drainage through joints in permeable pavements, and help prevent edge damage by minimizing direct contact between adjacent blocks during mechanical compaction.

- k. Chamfers: A chamfer, or beveled edge, around the wearing surface of the paving unit is desirable to enhance both durability and appearance. Chamfers reduce the likelihood of edge spalling or cracking under pedestrian or light vehicular traffic, and contribute to improved visual definition of block joints. The width and depth of chamfers shall be subject to review and approval by the Engineer, based on the functional and aesthetic requirements of the project.

7.10.4. Manufacturing / Casting

All solid concrete kerbs shall be factory-manufactured using an approved pressing method, ensuring a consistent and compacted product of high quality. The compaction pressure applied during manufacture shall not be less than 5 MN/m², uniformly distributed over the full surface area of each unit. The concrete mix shall be prepared using accurately batched materials, mechanically mixed to achieve a homogeneous composition with uniform color and consistency. Curing shall be carried out under controlled conditions to ensure the units develop the required strength and durability before delivery or installation.

7.10.5. Sampling and Testing

The Engineer or their designated representative shall be granted full access to inspect and sample paving units at the manufacturing facility from batches prepared for delivery. The lot size and sampling procedure for quality control testing, including assessments of compressive strength, water absorption, dimensional accuracy, and abrasion resistance, shall be jointly agreed upon by the supplier and the Engineer prior to dispatch.

Testing for compressive strength, absorption, and dimensional tolerances shall be carried out in accordance with ASTM C140/C140M, using a minimum of three (3) test specimens per property. Dimensional checks shall be performed on these specimens before mechanical testing. Abrasion resistance shall be assessed using at least two (2) distinct specimens, tested in accordance with ASTM C418. Each of these tests shall be conducted on independently sampled units, ensuring no specimen is reused across test categories.

7.10.5.1. Visual Inspection

All paving units shall be structurally sound and free from any defects that may hinder proper installation or compromise their strength and functional performance. Minor surface imperfections, such as small cracks or edge chipping that occur as part of standard manufacturing, handling, or transportation processes, shall be considered acceptable provided they do not impair the unit's intended performance or aesthetics in the finished pavement.

7.10.5.2. Rejection

If any batch of units fails to meet the specified requirements upon inspection or testing, the manufacturer may elect to re-sort the batch. A new sample set shall then be selected by the Engineer or authorized representative from the retained portion of the same lot and subjected to retesting at the contractor/manufacturer's expense. Should the retested specimens also fail to comply with the specified criteria, the entire lot shall be deemed non-conforming and rejected.

7.10.6. Construction Method

Interlocking block paving consists of three layers:

- a. **Improved Sub-grade:** Prepared as for a conventional road, with a minimum thickness of 20 cm, conforming to the requirements of **Clause 3.8**.
- b. **Laying Course:** A carefully screeded, compacted layer of "Sylhet" coarse sand with a fineness modulus ≥ 1.8 , and a minimum thickness of 5 cm after compaction.
- c. **Surface Course:** The interlocking paving blocks themselves, of approved size, shape, color, texture, and finish.

Edge restraint is essential to prevent lateral movement and displacement of blocks. It is normally provided using precast concrete kerbs.

7.10.6.1. Basic Paving Operations

The paving process shall follow a systematic sequence to ensure proper alignment, compaction, and interlock of the paving units. This includes:

- (a) Preparing and carefully screeding the sand laying course to a uniform thickness and level;
 - (b) Placing the interlocking blocks accurately, starting from a fixed edge and maintaining tight joints;
 - (c) Completing edge restraint installations and cutting blocks to fit at boundaries;
 - (d) Compacting the laid surface using a plate vibrator to set the blocks and integrate jointing sand.
- All operations shall be performed progressively to cover an area sufficient for efficient compaction, typically 15–20 m² per section.

7.10.6.2. Edge Restraint

- a. Pre-cast concrete kerbs shall be installed before paving begins to serve as edge restraints, ensuring the interlocking blocks remain confined and structurally stable over time.

b. Care must be taken to ensure that the kerb foundation does not extend beyond the kerb face, as this may obstruct block placement. Similar attention shall be given to features such as manholes and gully surrounds.

c. Edge restraint is required even where special edge blocks are used to terminate the paving pattern.

d. Where full-sized blocks cannot be accommodated along the edges, cut blocks shall be used to fill the remaining gaps. Cutting may be carried out using appropriate machines or hand tools, depending on the required precision.

e. Very small gaps, typically less than 40 mm in width, may be filled using a sand-cement mortar mix in a ratio of 4:1 to ensure a tight and stable finish along the edge.

7.10.6.3. Laying course

The laying course shall consist of approximately 50 mm thick, sharp-washed “Sylhet” sand after vibration. The sand shall contain no more than 3% silt and clay by weight, and not more than 15% retained on a 2.36 mm sieve. The sand must be uniform in type and moisture content, spread to a smooth level without uneven pre-compaction.

To maintain consistency, sand shall be sourced from a single location, allowed to drain before use, and covered to minimize moisture variation.

7.10.6.4. Screeding to Level

Screeding shall be carried out using traditional methods. For roads and footways up to 5 m wide, screeding may be done from the kerbs. For wider areas, temporary screed rails set to level shall be used.

Careful screeding not only results in a better surface but also improves block placement. A cambered screed board shall be used for roads or footpaths with a cambered cross-section.

7.10.6.5. Surcharge

After final vibration, blocks may settle below their original level due to compaction of the laying sand and its movement into block joints. Therefore, sand should be laid with a surcharge, typically 5–15 mm, depending on sand type and moisture content. The final level should be checked after laying the first few meters and periodically thereafter. If the final level is found incorrect, the blocks may be lifted and stacked, and the sand thoroughly raked and rescreened at a new level.

7.10.6.6. Surface course

Initial block placement requires special care to ensure alignment and pattern accuracy. Blocks must be placed at the correct angle against a fixed starting edge, such as a row of concrete channel blocks. Each block shall be placed carefully to avoid disturbing adjacent units. A standard laying pace can typically be achieved only after the initial three or four rows have been accurately set. However, with a herringbone pattern where the blocks are at 90° to the centerline, half blocks should be fitted at the starting line.

7.10.6.7. Laying

Blocks shall be placed carefully to avoid disturbing adjacent units. Efficient laying speed is typically achieved after the first three to four rows are properly aligned and set.

If joints begin to open, blocks shall be tapped together using a rubber mallet. Care must be taken not to tilt blocks by stepping or kneeling on the leading edge of the laying face.

Block laying shall continue until a sufficient area (approximately 15–20 m²) is ready for vibration. Light equipment or foot traffic may temporarily disturb the surface, which shall be corrected during final vibration or ironed out by the plate vibrator.

7.10.6.8. Compaction of road bed/paving blocks with plate vibrator

A plate vibrator shall be used to compact the roadbed before block placement and to initially set the blocks after laying. The vibrator shall have a plate area between 0.2 and 0.3 m² and a centrifugal force of approximately 1.0 ton.

7.10.6.9. Filling the Joints

Following initial vibration, fine sand (as per the grading in Table 7.10-1) shall be swept across the surface and vibrated into the joints using two or three passes of the plate vibrator. Surplus sand shall then be swept off the surface.

Table 7.10-1: Gradation for joint filling sand.

Sieve Size mm	% Passing by Weight
2.36	100
1.18	90 - 100
0.600	60 - 90
0.300	30 - 60
0.150	15 - 30
0.075	5 - 10

7.10.6.10. Paved Surface Tolerance

The final paved surface shall not deviate by more than ± 5 mm over a 3-meter straightedge. Joints shall be uniformly filled and shall not exceed 3 mm in width as per EN 1338. Localized depressions or protrusions shall be corrected immediately before acceptance

7.10.6.11. Permeable Paving

For locations requiring stormwater control or sustainable urban drainage, permeable interlocking concrete paving blocks may be used, subject to approval of the Engineer. These shall conform to ASTM C1781/C1782 or equivalent EN standards.

7.10.6.12. Performance Requirement

Upon completion of the works, the Contractor shall be responsible for the performance of the pavement for a minimum period of 12 months. Any observed defects, including settlement, surface irregularities, joint failure, or loss of interlock, shall be rectified by the Contractor at their own cost and to the satisfaction of the Engineer.

7.10.7. Measurement

The unit of measurement shall be the square meter (m^2) of completed and accepted interlocking concrete block pavement of specified thickness, measured in plan. This shall include all associated works such as *sub-grade preparation*, sand bedding/ laying course, supply and installation of paving blocks, edge restraint construction, cutting and fitting, joint filling, final compaction, and all necessary sampling, testing, and quality control measures as specified or directed by the Engineer.

7.10.8. Payment

The payment shall constitute full compensation for all works associated with the construction of the interlocking concrete paving block surface, including the cost of factory-manufactured paving units, labor, subgrade and laying course preparation and compaction, supply and application of jointing sand, cutting and fitting of blocks, edge restraint installation, cement-sand mortar (where required), transportation, handling, equipment, testing, quality control, and all other materials and incidental works necessary to complete the item as per the specification and Engineering drawings.

Pay items shall be:

Pay Items	Description	Unit
7.10.1	Supply and construction of interlocking concrete paving block	Sq. meter
7.10.2	Supply and construction of solid concrete permeable interlocking paving block	Sq. meter

7.11. Pre-cast Concrete Units for Median/ NMT Lane Separator/ Roundabout/ Footpath

7.11.1. General

This section of the specification covers the technical requirements for precast concrete roadside safety units, including kerbs, channels, edging blocks, quadrants, corner angles, offlets, and radiused kerbs, intended for use in medians, NMT (Non-Motorized Traffic) lane separators, roundabouts, footpaths, and other associated features of the road network. These components are integral to achieving well-defined, safe, and durable roadside environments by providing traffic guidance, pedestrian protection, surface water drainage, and functional demarcation between different user domains.

The specifications outlined herein are adapted and harmonized with the provisions of:

- IS 5758:2020 - *Precast Concrete Kerbs, Channels, Edging and Quadrants*
- BS EN 1340:2003 - *Concrete Kerb Units – Requirements and Test Methods*

The dimensional standards, interlocking configurations, tolerance requirements, material and physical requirements, construction procedures, testing protocols and related features prescribed in this document are aligned with internationally recognized standards mentioned above and have been carefully adapted to suit the operational and environmental conditions encountered in roadway infrastructure projects managed by the Roads and Highways Department (RHD) of Bangladesh. This section shall be read in conjunction with the RHD Road Safety Engineering Manual 2024, which provides supplementary illustrations, technical guidance, and explanatory details necessary for a complete understanding of the functional, structural, and safety performance of each precast concrete unit type.

The work under this specification shall consist of precast concrete units, including end protection⁸ for medians and NMT lane separators, conforming to lines, levels, typical cross-sections, and locations shown in the Engineering drawings and as instructed by the Engineer, in accordance with these technical specifications.

7.11.2. Precast Concrete Units

For detailed descriptions of typical precast concrete units, including kerbs, channels, edging blocks, quadrants, angles, offlets, and radiused kerbs, profiles, and applications of these units, refer to the RHD Road Safety Engineering Manual 2024.

⁸ Refers to specially shaped or reinforced kerb units (like tapered, bull-nosed, or sloped-end kerbs) placed at the beginning and end of a median or separator. This shall be smooth, safe transitions that guide vehicles and non-motorized traffic safely around or onto the structure, reducing the risk of collision, tire damage, or injury.

7.11.3. Interlocking Properties

Where specified, precast concrete kerbs and related units shall include interlocking features, such as tongue and groove, side notching, or base keying, to ensure dimensional alignment, resistance to displacement, and enhanced structural continuity without relying solely on mortar. All interlocking dimensions and tolerances shall comply with relevant standards and be verified for drainage compatibility. Refer to the RHD Road Safety Engineering Manual 2024 for acceptable interlocking types, manufacturing tolerances, and illustrative configurations.

7.11.4. Gutter Features

Gutters integrated with or placed adjacent to kerbs shall be provided to channel surface runoff, protect pavement edges, and ensure a smooth transition between the road and kerb face. Gutter design shall consider slope, surface texture, and joint treatment to ensure hydraulic efficiency and structural performance. Design types, dimensions, and integration methods are detailed in the RHD Road Safety Engineering Manual 2024.

7.11.5. Designation of Sizes for Precast Concrete Units

Precast concrete kerbs, channels, edging blocks, quadrants, angles, and associated fittings are typically designated based on their key dimensional properties. The designation follows a consistent order to clearly communicate the size, simplify manufacturing processes, and ensure correct on-site installation.

- **Designation Format:**

The dimensions are indicated in the following sequence:

1. Horizontal Dimension (Length) - the longer face that will be aligned horizontally after laying.
 2. Vertical Dimension (Height) - the face that will be oriented vertically after installation.
 3. Thickness - the cross-sectional width or depth.
- Special Cases: For units featuring curves (e.g., radiused kerbs) or unique shapes (e.g., quadrants), dimensions related to the radius or arc length may also be specified separately, in addition to the standard length, height, and thickness.
 - Facing or Decorative Finishes: If a unit has a textured, colored, or decorative facing layer, it shall be described distinctly, but shall not be included within the dimensional designation.

7.11.6. Tolerances for Precast Concrete Units

Manufacturing tolerances ensure that kerb units fit together correctly and maintain the designed line and level after installation. Tolerances must be strictly controlled to maintain structural, visual, and safety performance.

The permissible deviations from the declared work dimensions are:

- Length:
 $\pm 1\%$ to the nearest millimeter with a minimum of 4 mm, not exceeding 10 mm
- Height and Thickness (for faces):
 $\pm 3\%$ to the nearest millimeter with a minimum of 3 mm, not exceeding 5 mm.
- Other Parts (non-face dimensions):
 $\pm 5\%$ to the nearest millimeter with a minimum of 3 mm, not exceeding 10 mm.
- Consistency Within a Single Unit:
The maximum allowable difference between two measurements of the same dimension on a single unit must not exceed 5 mm.
- Standard radii are typically in the range of R15 to R50 mm, depending on the kerb type and application, and must be clearly indicated in the kerb profile Engineering drawings for compliance and quality control.

7.11.7. Permissible Deviations on Flatness and Straightness

Flatness of faces and straightness of edges of precast concrete units are critical for visual quality and for ensuring smooth alignment during installation, especially in high-speed or high-traffic areas. The permissible deviations are governed by the gauge length used during inspection, as shown in Table A1.

- **Flatness:** Maximum allowable convexity or concavity along the traffic-facing surface measured with a straight edge.
- **Straightness:** Deviation along the kerb edge line should remain within the stated permissible limits to avoid alignment irregularities.

Table 7.11-1: Permissible deviations on flatness and straightness.

Gauge Length (mm)	Permissible Deviation (mm)
300 mm	± 1.5 mm
400 mm	± 2.0 mm
500 mm	± 2.5 mm
800 mm	± 4.0 mm

7.11.8. Materials

7.11.8.1. Cementitious Materials

All cementitious components used in the production of interlocking concrete paving blocks shall comply with the relevant ASTM specifications listed below. The materials shall be free from impurities that adversely affect the performance or durability of the concrete mix.

- Ordinary Portland Cement: ASTM C150/C150M – Standard Specification for Portland Cement
- Blended Hydraulic Cements: ASTM C595/C595M – Types IS or IP⁹
- Performance-based Hydraulic Cement: ASTM C1157/C1157M
- Hydrated Lime (Type S): ASTM C207 – For supplementary use where specified
- Fly Ash: ASTM C618 – Class F or C, subject to compatibility
- Ground Granulated Blast-Furnace Slag (GGBFS): ASTM C989/C989M
- Silica Fume: ASTM C1240 – For enhanced durability and reduced permeability

7.11.8.2. Aggregates

Aggregates used in the manufacturing of paving units shall meet the physical and durability requirements of ASTM standards. Grading compliance is not mandatory unless otherwise specified by the Engineer, but material quality and cleanliness must be ensured.

- Normal Weight Aggregates: ASTM C33/C33M – Standard Specification for Concrete Aggregates
- Lightweight Aggregates: ASTM C331/C331M – For Concrete Masonry Units

All aggregates shall be clean, durable, and free from organic matter, clay lumps, soft particles, or other deleterious substances.

7.11.8.3. Chemical Admixtures and Mixing Water

All chemical admixtures used in the concrete mix shall comply with the following ASTM standards, and shall not impair the durability, strength, or setting characteristics of the concrete:

- Air-Entraining Admixtures: ASTM C260/C260M
- Water-Reducing, Retarding, and Accelerating Admixtures: ASTM C494/C494M

⁹ IS = Portland-Slag Cement: A blend of Portland cement and granulated blast-furnace slag. The slag improves durability, sulfate resistance, and reduces heat of hydration; IP = Portland-Pozzolan Cement: A blend of Portland cement and pozzolanic materials such as fly ash, volcanic ash, or silica fume. It enhances long-term strength, reduces permeability, and improves resistance to alkali-silica reaction.

- Color Pigments for Integrally Colored Concrete: ASTM C979/C979M

Water used for mixing or curing shall be clean and potable, conforming to ASTM C1602/C1602M. It must be free from deleterious substances such as oils, acids, alkalis, salts, organic matter, or other impurities that may compromise setting time, strength development, or long-term durability.

7.11.8.4. Steel Reinforcement

Steel reinforcement must follow ASTM A615 or ASTM A617M or ASTM A706M as specified in the Engineering drawings or as directed by the Engineer.

7.11.9. Physical Requirements

- a. All precast units shall be structurally sound and free from any cracks, surface defects, or deformities that could affect their proper placement, structural integrity, or in-service performance. Minor chipping caused by standard handling or transportation practices shall not constitute grounds for rejection, provided the functionality of the unit remains unaffected.
- b. Bending and compressive strength - The average bending strength of a set of five precast units shall not be less than 5.0 N/mm², and no individual unit shall exhibit a bending strength below 4.0 N/mm², when tested in accordance with the procedure outlined in IS 5758: 2020. The test for bending strength shall be carried out after 14 days of producing the unit. For precast elements such as quadrants, angles, offlets, and radiused kerbs, or where standard bending strength testing is not feasible due to shape or geometry, compressive strength testing shall be conducted by extracting a concrete core. In such cases, the average compressive strength of the core samples shall be a minimum of 30 N/mm², with no individual unit falling below 25.8 N/mm².
- c. Water absorption - The average water absorption of three test specimens, when determined in accordance with the procedure specified in IS 5758:2020, shall not exceed 6 percent by mass.
- d. Dimensional Tolerance - All kerbs shall be manufactured according to approved profiles as per Engineering Drawings. When measured at random, the average of twelve readings (either length, width, or height) from three (minimum) sampled units shall conform to the tolerance limits as described in sub-section 7.11.6.
- e. Angles and Arris - All product angles, except those intentionally splayed or chamfered, shall be true right angles, subject to the tolerances in sub-section 7.11.6. Arris shall be clean, sharp (unless specified as rounded), and the wearing surfaces shall be true and free from warping or irregularity, within specified tolerances.

7.11.10. Manufacturing/Casting

All solid concrete kerbs shall be factory-manufactured using an approved pressing method, ensuring a consistent and compacted product of high quality. The compaction pressure applied during

manufacture shall not be less than 5 MN/m², uniformly distributed over the full surface area of each unit. The concrete mix shall be prepared using accurately batched materials, mechanically mixed to achieve a homogeneous composition with uniform color and consistency. Curing shall be carried out under controlled conditions to ensure the units develop the required strength and durability before delivery or installation.

7.11.11. Sampling and Testing

The Contractor shall ensure that all precast concrete units are tested to verify compliance with dimensional tolerances, physical properties, and visual standards, as specified. A minimum of eight (8) units shall be sampled from every batch or consignment of 2,000 units or part thereof, representing the same type and production lot. Of these, all units shall be inspected for dimensional accuracy and visual quality, three (3) units tested for water absorption, and five (5) units for bending strength and, where applicable, facing/backing layer integrity. All testing shall be performed in accordance with applicable standards mentioned in this Specification, or as directed by the Engineer. Whether the units are manufactured by an external supplier or produced directly by the Contractor, the Engineer or their authorized representative shall be granted full and unrestricted access to inspect the production process, review material sources, and sample materials or finished units at the manufacturer's plant or the Contractor's fabrication facility, as applicable. All testing arrangements, including facilities, equipment, personnel, and logistics, shall be provided and funded by the Contractor, either through in-house laboratories or manufacturer testing facilities, subject to approval. Upon request, the manufacturer shall provide certificates of compliance and allow independent verification testing at a mutually agreed laboratory.

7.11.11.1. Visual Inspection

All units shall be structurally sound and free from any defects that may hinder proper installation or compromise their strength and functional performance. Minor surface imperfections, such as small cracks or edge chipping that occur as part of standard manufacturing, handling, or transportation processes, shall be considered acceptable provided they do not impair the unit's intended performance or aesthetics in the finished pavement.

7.11.11.2. Rejection

If any unit fails to meet the specified strength or absorption requirements, a second set of samples from the same lot shall be tested. If the second set also fails, the entire batch shall be deemed non-conforming and rejected.

7.11.12. Construction Methods

7.11.12.1. Construction of median/ NMT lane separator/ roundabout/ footpath

The median/ NMT Lane separator/ Roundabout shall be constructed as per the drawing. Construction on existing carriageways may require excavation of the existing pavement as shown on the Engineering Drawings. All joint and concrete work shall be cured properly for a minimum period of 7 (seven) days.

7.11.12.2. Installation of Pre-cast Kerbs

- a. Only high-quality kerbs approved by the Engineer shall be allowed to be used for media / NMT lane separator/ roundabout/ footpath.
- b. The pre-cast units shall be fixed or placed as per the details indicated in the Engineering Drawings and typical sectional details.
- c. Bedding concrete shall be Class 15 with stone aggregates, and joints shall be filled with 1:3 cement-sand mortar, finished with recessed pointing as per the approved sample or as directed by the Engineer.
- d. All pre-cast units shall be presoaked and adequately moistened before being laid on bedding concrete or prior to mortar application. Curing of all concrete and joints shall be for at least 10 days.

7.11.12.3. Installation of gutter

Depending on design, functional needs, and construction methodology, gutters may be integrated into the kerb or other precast units as a single monolithic unit or constructed as a separate adjacent slab. In both cases, the design of the gutter shall consider slope, surface texture, and width to ensure both hydraulic performance and durability.

Key Design Features for Gutters:

- Slope for Drainage:
Gutters must be laid with a minimum longitudinal slope (typically 0.5% to 2%) to facilitate water flow toward drainage inlets.
- Cross-Section Shape:
 - Flat-bottomed Gutters: Easy to construct but may allow shallow water pooling.
 - V-shaped or Dished Gutters: Improve water velocity and reduce debris settlement.
- Surface Texture:
Should be smooth enough to promote flow but rough enough to provide skid resistance for vehicles and pedestrians.

- **Width Consideration:**
Typical gutter widths vary between 300 mm and 600 mm, depending on road type and drainage requirements.
- **Joint Treatment:**
Proper sealing of joints between kerb and gutter elements is important to prevent water infiltration into the subgrade.

7.11.13. Measurement

Pre-cast concrete units used in medians, NMT (Non-Motorized Traffic) lane separators, roundabouts, footpaths, and other roadside features shall be measured in linear meters of the completed and accepted work, conforming to the dimensions and alignment shown in the Engineering Drawings or as directed by the Engineer. The length shall be measured along the centerline of the top finished surface. Measurement shall include different types of linear precast components such as kerbs, channels, edging blocks, quadrants, angles, offlets, and kerbs with integrated gutters. Backfilling shall be measured and paid separately under Section 7.12.

7.11.14. Payment

Payment for precast concrete units shall be made in linear meters, which shall include full compensation for furnishing all labor, materials, transport, tools, and equipment, along with excavation, cutting of pavement, bedding, haunching, jointing, end protection, mortar filling, and any other incidental works necessary for proper installation, alignment, and finishing of the units to the satisfaction of the Engineer.

Pay items shall be:

Pay Items	Description	Unit
7.11.1	Supply and installation of pre-cast concrete units for medians, footpaths, NMT zones, or similar features	Lin. meter
a)	Kerb (Profiles: square, bull-nose, splayed, half-battered, stepped half-battered, full battered, etc., or as per Engineer Drawings)	
b)	Angles	
c)	Quadrants	
d)	Channels	
e)	Edging blocks	
f)	Offlets	
g)	Radiused kerb	
7.11.2	Supply and installation of pre-cast concrete kerbs for medians, footpaths, NMT zones, or similar features integrated with gutter/channel section	Lin. meter

7.12. Backfilling of Median/NMT Lane Separator/Roundabout

7.12.1. Description

The item shall consist of backfilling of constructed median/NMT lane separator /roundabout and similar road features as shown in the Engineering drawings or as instructed by the Engineer.

7.12.2. Materials

The fill material shall be natural earth free from roots, organic matter, and other deleterious materials. The material must be free from stones and other bigger particles, which may cause severe injuries in case a vehicle hits a Median/NMT Lane separator/roundabout.

7.12.3. Construction

Backfilling shall be carried out in successive layers not exceeding 150 mm in loose thickness, placed uniformly and compacted to the required density for the full width of fill as shown on the Engineering drawings and in such lengths as are suited to the watering and compaction methods utilized. Watering and rolling shall be performed as needed. The fill area shall be as shown in the Engineering drawings or as instructed by the Engineer.

7.12.4. Measurement

Backfilling of median / NMT lane separator/ roundabout shall be measured in cubic meters of materials completed and accepted on the site.

Excavation and removal of flexible pavement shall be measured in cubic meters in its original location, and volume determined in cubic meters by the average end area method.

7.12.5. Payment

Backfilling of median/ NMT lane separator/ roundabout with earth shall be paid for at the contract unit rate per cubic meter. Payment shall be the full compensation for materials, labor, equipment, and all other incidentals necessary to complete the work.

Excavation and removal of flexible pavement shall be paid at the contract unit rate per cubic meter. The payment shall be full compensation upon completion of the work.

Pay item shall be:

Pay Items	Description	Unit
7.12.1	Earth filling in the road median / NMT lane separator/roundabout	Cu meter

7.12.2	Roadway Excavation and the removal of existing flexible pavement structure.	Cu meter

7.13. Dismantling Damaged and Reuse of Pre-cast Concrete Units

7.13.1. Description

The work shall consist of furnishing all necessary tools, equipment, and materials for dismantling of damaged precast concrete units or cleaning and recovering kerbstones in accurate condition for reusing in construction work.

7.13.2. Construction

The existing precast concrete units shall be recovered from the original construction area being dismantled mechanically or manually, and during dismantling, care shall be taken so that a considerable number of units are saved. After necessary cleaning, these units shall be installed at the same locations or at other locations as per the Engineering drawings.

The joints of units shall be filled with cement mortar in the proportion of 1 part of cement to 4 parts of sand. Curing by water to these works shall be done for at least 7 days.

7.13.3. Measurement

The completed work of dismantling and reinstallation of precast concrete units shall be measured in linear meters along the center line of the construction line. The measurement shall be recorded before dismantling and after installing separately. If all the units are not used in the new work, the surplus dismantling units shall be stockpiled and handed over to the representative(s) of the Engineer.

7.13.4. Payment

The work measured above shall be paid for at the contract unit rate in linear meters. The payment shall be full compensation for furnishing materials, labor, tools, equipment, and incidentals necessary for the proper completion of work as specified in the contract documents or as directed by the Engineer.

Pay items shall be:

Pay Items	Description	Unit
7.13.1	Dismantling of the existing precast concrete unit	Lin. meter
7.13.2	Reinstallation of precast concrete unit	Lin. meter

7.14. Painting of Median/NMT Lane Separator/Roundabout

7.14.1. Description

This specification covers the material and application requirements for high-intensity reflective paint to be used on medians, concrete barriers, roundabouts, and similar roadside structures. The paint system enhances the visibility of such structures under both daytime and nighttime conditions, thereby improving road safety.

7.14.2. Materials All materials used shall conform to the following standards:

Reflective Paint: High-intensity, weather-resistant paint conforming to BS EN 1871, suitable for application on concrete or masonry surfaces. The paint shall be free from lead and other toxic heavy metals and shall maintain its color, retro-reflectivity, and adhesion under outdoor exposure.

Primer: A high-penetration, concrete-compatible primer (e.g., Patron sealer) shall be applied prior to the reflective paint to ensure strong adhesion and effective sealing of the substrate, particularly on uncoated concrete, plastered brick, or masonry surfaces. The primer shall be suitable for exterior use, compatible with the selected reflective paint system, quick-drying (surface dry within 1 hour at 25°C), non-yellowing, and capable of minimizing absorption of the topcoat. Only primers approved by the Engineer based on manufacturer data and demonstrated field performance shall be used.

Performance Requirements (as per BS EN 1436):

- **Daytime Visibility:**
 - *White Paint:* Luminance coefficient (Q_d) ≥ 130 mcd/m²/lux
 - *Yellow Paint:* Luminance coefficient (Q_d) ≥ 100 mcd/m²/lux
- **Nighttime Visibility:**
 - *White Paint:* Retro-reflectivity (R_L) ≥ 100 mcd/m²/lux
 - *Yellow Paint:* Retro-reflectivity (R_L) ≥ 80 mcd/m²/lux
- **Skid Resistance** (if applicable for walkable or trafficked surfaces): SRT ≥ 45
- **Color and Contrast:** Black and white or black and yellow reflective bands with a minimum width of **100 mm each**, unless otherwise specified in the Engineering drawings.

7.14.3 Application Method

- Surfaces shall be cleaned of all dust, grease, and debris prior to primer application.
- Primer shall be applied uniformly and allowed to dry fully.
- Two coats of reflective paint shall be applied over the primed surface using brush, roller, or airless spray, following the manufacturer's instructions.

- The second coat shall be applied only after the first coat is dry and cured, typically not less than 24 hours.
- Painting shall not be carried out during rain or when the surface or ambient temperature is below 10°C or above 40°C.
- The painted surfaces shall exhibit uniform color, texture, and reflectivity.

7.14.4 Inspection and Testing

- The Engineer may conduct retro-reflectivity testing using a portable retro-reflectometer to verify RL values.
- Daytime luminance and color shall be verified visually and through manufacturer certification.
- Paint adhesion and thickness shall comply with manufacturer recommendations and may be subject to random field testing.

7.14.2. Measurement

Reflective painting median/NMT Lane Separator/roundabout or similar features shall be measured in square meters (m²) of finished, painted surface area, completed and accepted by the Engineer.

7.14.3. Payment

Payment for reflective painting on median/NMT Lane Separator/roundabout or similar features shall include full compensation for surface preparation, primer, reflective paint, labor, equipment, tools, testing, and all incidental works necessary to complete the item to the satisfaction of the Engineer.

Pay item shall be:

Pay Item	Description	Unit
7.14.1	Reflective painting of road medians/ NMT lane separator/ roundabout or similar features	Sq. meter

7.15. Demolition and Removal of Existing Median and Barrier

7.15.1. Description

This item covers the controlled demolition and removal of existing road medians and barriers, including kerb-type medians, cast-in-place or precast concrete medians, and New Jersey-type barriers, as shown in the Engineering drawings or as directed by the Engineer. It also includes the removal of

associated backfill or filling material, which shall be transported to a designated disposal area or temporarily stockpiled for potential reuse as instructed by the Engineer.

7.15.2. Method

- The Contractor shall prepare and submit a detailed demolition methodology, including sequence, equipment, safety controls, and debris management, for approval by the Engineer at least fourteen (14) days prior to commencing the works.
- Demolition shall be carried out using appropriate tools and machinery, ensuring that only the designated sections are removed while adjoining or remaining portions of the median or barrier are left intact and undisturbed.
- Special care shall be taken to avoid damage to adjacent pavement, structures, and utilities. In the event of any damage to existing pavement caused by demolition activities, the Contractor shall restore the affected area to its original condition at no additional cost, using materials and methods approved by the Engineer.
- All work shall comply with applicable safety standards, including the installation of advance warning signs, barricades, and flagmen where demolition occurs near live traffic.

7.15.3. Measurement

Demolition and removal of medians and barriers shall be measured in linear meters along the centerline of the structure actually demolished, removed, and accepted by the Engineer. Any backfill or fill material removed as part of the process shall be included within this measurement unless otherwise specified.

7.15.4. Payment

Payment shall be made at the contract unit rate per linear meter of median or barrier demolished and removed. The rate shall be full compensation for providing all labor, tools, equipment, materials, safety measures, approved demolition method, transport, and disposal or stockpiling of debris and backfill, and for performing all work required to complete the item in accordance with the Engineering drawings, specifications, and the Engineer's instructions.

Pay item shall be:

Pay Item	Description	Unit
7.15.1	Demolition and removal of existing median (including filling material)	Lin. meter

7.16. Crash Barriers

7.16.1. General

Crash barriers are critical roadside safety devices designed to contain and redirect errant vehicles, thereby mitigating the severity of crashes and preventing vehicles from departing the roadway into hazardous zones. This section covers the supply, construction, and installation of crash barriers in accordance with the design drawings and the technical requirements specified in this document. All materials, performance characteristics, and installation procedures shall conform to internationally recognized standards, including relevant provisions of EN standards, AASHTO specifications, or equivalent, such as the Manual of Specifications and Standards for Four Laning of Highways (SP:84-2019).

7.16.2. Placement Criteria

Crash barriers are primarily used as longitudinal roadside barriers and median barriers and should be strategically placed considering the following factors:

- **Roadside Obstacles:** Barriers should be used to shield hazardous elements such as bridge piers, abutments, culverts, headwalls, retaining walls, lighting supports, traffic signs, signal supports, trees, and utility poles.
- **Median Protection:** Barriers should be installed on highways with narrow medians to prevent head-on collisions due to out-of-control vehicles crossing into opposing lanes.

The design engineer shall determine the precise placement of crash barriers, considering lateral offsets and flare rates while ensuring uniform clearance between traffic and potential hazards. The following placement guidelines should be followed:

- **General Placement:**
 - Barriers should be positioned as far from traffic lanes as feasible, with a minimum offset of 2.5 meters where possible.
 - The distance between the barrier and the hazard should be at least equal to the expected deflection of the barrier upon impact.
 - A minimum clearance of 60 cm should be maintained between the barrier and the edge of embankment slopes to prevent vehicle destabilization.
 - A lower flare rate may be used in situations where significant grading is necessary to create a smooth transition from the traveled way, provided there is sufficient right-of-way.
 - If adjacent carriageways are at the same elevation, the barrier should be centrally placed in the median with appropriate drainage considerations.

- When carriageways are at different elevations, the placement of median barriers should account for the slope between them to ensure optimal safety and stability.
- Reflectivity:
 - Crash barriers must be fitted with delineators to enhance nighttime visibility.
- Raised Curbs:
 - Raised curbs and drains should not be placed between the traveled way and crash barriers, as they may destabilize vehicles before impact, compromising safety and redirection effectiveness.

7.16.3. Warrants for Crash Barrier Installation

Crash barriers shall be installed at the following locations:

- a. Where embankments exceed a height of 3 meters.
- b. Where embankments are retained by structures such as retaining walls.
- c. At medians with widths less than 4.5 meters, with barriers provided for both travel directions.
- d. On the valley side of highways in mountainous or steep terrain.
- e. Between the main carriageway and footpaths on bridges.
- f. On the highways with AADT more than 20,000 PCUs and with median widths less than 9m, median barriers are required. The probability of a vehicle crossing the median is relatively low, and median barriers in such cases are optional.
- g. Median barriers to shield fixed objects in a narrow median. If necessary, median barriers should be flared to encompass a fixed object, which may be a lamp post, foundation of overhead signs, bridge pier, etc.
- h. Medians with widths ranging from 9 to 15 meters do not require barriers unless there is a documented history of median crossovers.
- i. Where a road contains numerous closely spaced median openings, barriers may be impractical due to the need for frequent end treatments.
- j. Before deciding on the installation of median barriers, an evaluation should be conducted, considering factors such as the number of median openings, accident history, road alignment, sight distance, design speed, traffic volume, and median width.
- k. Safety barriers shall be provided on curves with radii up to 450 m.

l. Safety for bridges/structures:

- Bridges Without Footpaths: Concrete crash barriers shall be installed at the edge of the carriageway on all new bridges to ensure vehicular containment and prevent vehicle runoff.
- Bridges With Footpaths: Pedestrian railings shall be installed on the outer side of the footpath, and a concrete crash barrier shall be placed between the carriageway and footpath in rural sections.
- Loading and Containment Levels (As per IRC:6-2017): Crash barriers must be designed to withstand vehicular impact forces based on their containment level. The following table summarizes the key containment levels and associated loading conditions:

Table 7.16-1: Containment levels bridge barriers.

Containment Level	Application	Vehicle Mass	Impact Speed	Impact Angle
P-1: Normal Containment	Bridges carrying expressways, national highways, state highways, or roads of similar importance.	15 kN (1.5 tons)	110 km/h	20 degrees
P-2: Low Containment	All other bridges except those over railways.	15 kN (1.5 tons)	80 km/h	20 degrees
P-3: High Containment	High-risk locations such as bridges over busy railway lines, complex interchanges, or hazardous sites.	30 kN (3 tons)	60 km/h	20 degrees

- Design Loading Criteria (Clause 209.7 of IRC:6):
 - Crash barriers should withstand an impact force of 150 kN (approx.) applied at 1.2 m height from the road surface.
 - Barriers should be capable of absorbing impact energy without excessive deflection, ensuring effective vehicle redirection.
 - Structural reinforcement shall be provided to meet containment requirements and prevent structural failure.

These containment levels and loading criteria ensure that crash barriers are appropriately designed to prevent vehicle penetration, minimize accident severity, and enhance overall roadway safety.

m. Any other location deemed necessary by the Engineer.

n. Restrictions:

- Metal beam and wire rope safety barriers shall not be installed upon a structure.
- For safety barriers on structures, only concrete rigid barriers shall be used.
- Wire rope safety barriers shall not be used on major or minor bridges.

7.16.4. Crash Barrier Types

Crash barriers are classified into three types based on their structural behavior:

- **Flexible Barriers:** These are the most yielding type, typically consisting of wire rope fencing. They absorb energy by deflecting significantly upon impact.
- **Semi-Rigid Barriers:** Metal beam/W-beam crash barriers fall into this category. They offer controlled resistance to limit deflection within acceptable limits.
- **Rigid Barriers:** Typically made of concrete, these barriers do not deflect upon impact, leading to higher impact severity but preventing vehicle penetration.

7.16.5. Concrete Crash Barrier/New Jersey Barrier

Concrete crash barriers shall be constructed using one of the following methods: cast-in-place with fixed forms, extrusion, or slip-forming. The choice of method shall be at the Contractor's discretion, subject to approval by the Engineer. If the extrusion or slip-form method is selected, detailed documentation and technical specifications must be submitted for review.

7.16.5.1 Material

- Concrete barriers shall be made using minimum C20 Class concrete or as specified in the Engineering drawings.
- Reinforcement shall consist of thermo-mechanically treated (TMT) deformed bars of grade S415.
- Expansion joints with pre-molded asphalt filler boards shall be provided at the junctions where crash barriers on structures meet barriers on embankments.
- Crash barriers on embankments shall be constructed in segments not exceeding 20 meters in length, with expansion joints at appropriate intervals using pre-molded asphalt filler boards.

7.16.5.2. Construction

- The location and alignment of crash barriers shall strictly follow the design drawings or be as directed by the Engineer.
- The finished barriers shall have a smooth and uniform surface, conforming to the specified horizontal and vertical profiles, free from irregularities such as lumps or sags.
- The top and exposed faces shall meet the prescribed tolerances.

Design and Installation Considerations

- The optimal median barrier height is 80 cm, considering vehicle direction, sight distance, structural integrity, and driver perception.
- The New Jersey-type barrier is the preferred design due to its efficiency in deflecting vehicles upon impact.
- Site-specific conditions may allow height variations up to 50 mm, but the lower slope height must be maintained between 20 cm and 35 cm to minimize vehicle overturning risks.
- Concrete barriers may be precast in segments up to 6 meters long, subject to transport and installation feasibility.
- The foundation thickness should be a minimum of 250 mm of cement concrete to provide lateral restraint. Longitudinal roadside concrete barriers must have a structurally stable footing design unless adequate earth support is present.
- Backfilling around barriers must be compacted in layers to match the surrounding earthwork.

Tolerances

- The horizontal alignment of barriers must not deviate by more than ± 30 mm from the planned road alignment.
- Successive segments must not vary by more than 6 mm from a straight line.
- Barrier faces must not deviate more than 12 mm when checked with a 3-meter straightedge.
- The barrier height above the adjacent carriageway or shoulder shall be maintained within ± 30 mm of the specified design.

End Treatment, Paint, and Reflectors

- **End Treatment:**
 - Roadside barriers shall have a tapered terminal end over a length of 8 to 9 meters.
 - Median barriers shall terminate away from median openings with a similar tapering treatment.
- **Color & Reflectors:**
 - Barriers shall be painted in yellow/black stripes as per approved specifications.
 - Reflectors (one-way or two-way) shall be installed at intervals as per approved Engineering drawings:
 - Edge barriers: Red/white reflectors
 - Median barriers: Yellow/black reflectors

7.16.5.3. Measurements

The measurement for all barriers shall be based on linear meters of fully constructed and approved barrier length, measured from end to end along the face of the concrete barriers, including approach

and departure sections. The contract unit rate shall encompass all costs associated with labor, materials, tools, equipment, and any other incidental expenses required to complete the concrete barrier construction in full compliance with the given specifications.

7.16.6. Metal Beam Crash Barrier/W-Beam

The installation of metal beam crash barriers shall involve the supply and erection of barriers as per the specified dimensions and designated locations shown in the Engineering drawings or as instructed by the Engineer. These barriers shall generally be placed on approaches to bridge structures, at locations where the embankment height exceeds 3 meters, and on horizontal curves to enhance safety.

7.16.6.1. Materials

- The metal beam rail shall be composed of corrugated sheet steel beams, conforming to the specified class, type, section, and thickness.
- Railing posts shall be fabricated from steel of the specified section, weight, and length as per the design drawings.
- All steel components, including rails, terminal sections, posts, bolts, nuts, hardware, and fasteners, shall be hot-dip galvanized to a minimum zinc coating of 0.55 kg/m².
- All railing elements must be free from abrasions, sharp edges, and deformations such as kinks, twists, or bends.

W-Beam Type Safety Barrier

- Composed of 3 mm thick steel “W” beam rail elements.
- Steel posts and spacers shall be channel sections of 75 × 150 mm, 5 mm thick.
- The height of the rail shall be 70 cm above ground level.
- Post spacing shall be 2 meters center-to-center.

Thrie-Beam Safety Barrier

- Uses similar posts and spacers as the W-beam system.
- The rail height shall be 85 cm above ground level.
- Though initially more costly, the thrie-beam barrier provides better impact resistance, particularly for shallow-angle collisions.

All metal beams, posts, spacers, and fasteners shall be galvanized after fabrication unless specified otherwise. The galvanization process for all steel parts shall conform to the relevant specifications mentioned in section 7.1.2.5.

7.16.6.2. Construction

The alignment and elevation of the railing must conform precisely to the specifications outlined in the plans. Before securing the railing in place, careful adjustments should be made to ensure seamless matching at adjacent joints, as well as consistent alignment and curvature along its entire length. Any necessary holes for field connections must be drilled with the railing correctly positioned on the structure to maintain proper grade and alignment.

Unless otherwise indicated in the Engineering drawings, steel posts for the railing shall receive a primer coat in the shop, followed by three coats of paint on the structural steel after installation, provided the sections are not galvanized. Any part of the assembly located below ground level must be coated with three layers of red lead paint.

Splices and end connections should adhere to the specified designs or those illustrated in the plans. These components must be strong enough to achieve the full design strength of the rail elements.

Installation of posts

Holes for posts should be either drilled or excavated to the depth specified in the plans. Alternatively, posts may be driven using approved methods and equipment, ensuring they are positioned accurately and remain free from deformation, burrs, or any form of damage.

Excavated or drilled holes should be sufficiently large to facilitate proper placement of posts and allow adequate space for backfilling and tamping.

The backfilling process should utilize selected earth or stable materials, applied in layers not exceeding 100 mm in thickness. Each layer must be thoroughly compacted and rammed to secure the posts or anchors firmly in place.

For post holes drilled into rock or anchor post holes, backfilling should be carried out using concrete.

Posts for metal beam guardrails on bridges must be bolted to the structure with washers as indicated in the plans. Anchor bolts should be positioned accurately using templates and verified for correct placement and elevation.

Erection

All guardrail anchors should be set and attached as specified in the plans or as directed by the Engineer.

Bolts and clips used to fasten the guardrail or fittings to the posts must be tightened securely with washers. Each bolt should extend at least 6 mm beyond the full nut unless such extensions pose a risk to traffic, in which case the bolts should be trimmed flush with the nut.

Railing installations should be carefully adjusted to ensure uniform longitudinal tension throughout the entire structure.

End treatment for the steel barrier and the Two-way Trapezoidal Reflectors

End treatments must integrate with safety barriers in a way that prevents spearing, vaulting, or rolling of vehicles upon impact, whether head-on or at an angle. The two recommended end treatments for steel barriers are the "Turned-down guardrail" and "Anchored in back slope."

The Turned-down guardrail involves gradually lowering the "W" or three beam section to ground level over a distance of 8 to 9 meters. This design allows the rail to collapse upon impact, enabling vehicles to pass over it without becoming airborne or unstable. To position the barrier terminal away from the roadway and reduce driver reactions to potential hazards, the turned-down rail should be flared outward from the traveled way. Suggested flare rates based on design speed and barrier type are presented in Table 7.17-01.

Table 7.16-2: Suggested Flare Rates

Design speed (km/h)	Flare rates	
	Rigid barriers	Semi-rigid barriers
100	17:1	13:1
80	14:1	11:1
65	11:1	9:1
50	8:1	7:1

Two-way trapezoidal reflectors (Red/White) should be installed at intervals as specified in the approved Engineering drawings.

For roads in cut sections or transitioning from cut to fill, barriers may be anchored into back slopes. The back slope covering the anchored portion should be graded flat, with side slopes ideally not exceeding a 10:1 ratio. The anchored section must develop adequate tensile strength to prevent rail pullout from the anchorage. Alternatively, the barrier can be anchored in an earth beam designed specifically for this purpose, ensuring that the beam itself does not pose a hazard to traffic. The earth beam should also be resistant to erosion. For "Turned-down guardrail" end treatments, no flaring should be incorporated.

Tolerance

Posts must be installed vertically with a deviation not exceeding 6 mm over a length of 3 meters. The railing barrier should be erected accurately, adhering strictly to the specified line and grade.

Surface protection

The AASHTO M 180 standard, titled "Standard Specification for Corrugated Sheet Steel Beams for Highway Guardrail," specifies requirements for zinc coatings on guardrails:

- Type I: Requires a minimum zinc coating of 550 g/m² (1.80 oz/ft²) per side, equivalent to 38.5 microns coating thickness per side.
- Type II: Requires a heavier zinc coating of 1100 g/m² (3.60 oz/ft²) per side, equivalent to 77 microns coating thickness per side.

7.16.6.3. Measurements

The length of completed metal beam railing barriers shall be measured in linear meters as per the approved design. Terminals and anchors of different types shall be included in the item. Any projection or anchorage beyond the end posts will not be measured for payment unless explicitly stated. The supply and installation of anchor bolts or devices for securing guardrail posts on bridges will be considered part of the overall construction and included in the cost of other related items. Excavation and backfilling carried out as part of this construction will not be separately measured for payment.

7.16.7. Flexible Wire Rope Barriers

7.16.7.1. General

The Flexible Wire Rope Safety Barrier (WRSB) is a type of roadside or median guardrail designed to enhance traffic safety. It consists of steel wire ropes mounted on flexible posts, with the primary function of preventing vehicles from leaving the roadway and colliding with fixed obstacles or hazardous terrain. Like other roadside barriers, WRSB systems work by either capturing or redirecting errant vehicles. There are two main types of cable barriers: low-tension and high-tension systems. High-tension barriers are generally preferred due to their ability to limit cable deflection to approximately 2.4 meters upon impact. These barriers consist of three or four pre-stretched cables supported by flexible posts and are installed under specific tension levels ranging from 9 to 40 kilonewtons (kN). Due to their inherent tension, these systems can maintain their integrity even after an impact that removes several posts, allowing the remaining portion to continue functioning effectively. However, improper installation and testing can result in severe accidents.

Characteristics

- **Tension:** High-tension WRSBs are typically tensioned to 25 kilonewtons (kN) during installation, though this may vary depending on weather conditions, the type of WRSB, and other influencing factors. Low-tension WRSBs, which are now less commonly used, have significantly lower tension levels, often close to zero.
- **Containment or Deflection:** Deflection-based WRSBs tend to be tensioned to a slightly higher level and generally incorporate four wire ropes. These barriers are usually shorter in length. Containment-based WRSBs, on the other hand, feature wire ropes that are spaced further apart, typically 150mm to 60mm, to maximize the catchment area.
- **Test Level:** Flexible Wire Rope Barriers (FWRBs) must meet the TL-4 test level for approval.
- **Slopes:** The cable barrier system is designed for use on slopes with a 1:6 vertical-to-horizontal ratio.
- **Clearance:** Upon impact, cable barriers can deflect between 2.5 meters and 3.6 meters. Due to this relatively large deflection range, these systems are generally not suitable for shielding fixed objects positioned closer than 2.5 meters from the traveled way. Even when clearance exceeds this minimum requirement, public perception often favors more robust barriers.

7.16.7.2. Materials

The WRSB system must conform to European Standard EN 1317-2.

- **Posts:** The posts should be Z-shaped, measuring 100x55x5mm, and hot-dip galvanized. The height should be 1430mm, with a portion embedded in concrete for stability. Post spacing typically ranges from 3 to 5 meters center-to-center, depending on road conditions. The spacing from the final post to the end anchor is 2 meters (6.5 feet), with approval required from the Engineer in charge.
- **Rope:** The rope should have a 19mm diameter, with a 3x7 strand configuration and pre-stretched by 35%. The height of the top rope from the road surface should be 790-930mm (+/- 30mm). Each meter of rope should weigh 1.17 kg, with a minimum tensile strength of 1370 N/mm² and a minimum breaking load of 17.7 tons.
- **Foundation Pit:** The pit dimensions for posts should be 350mm in diameter and 750mm deep. The pit size for end anchors may range between 3 to 6 cubic meters, depending on soil conditions. The required concrete strength should be 25 MPa.

A typical drawing is given below-

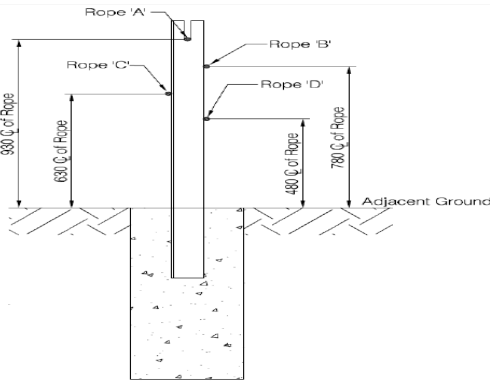


Figure 7.17-2: Typical WRSB system

7.16.7.3. Construction & Installation

The WRSB system is tensioned using a machine and hand pump to achieve the required tension levels during installation. All installation procedures must comply with EN 1317-2 or manufacturer recommendations, as directed by the Engineer in charge. The system should be installed on slopes with a 1:6 vertical-to-horizontal ratio. Given the potential for deflection between 2.5 and 3.6 meters, it is typically unsuitable for protecting objects within 2.5 meters of the traveled way.

To improve visibility and safety, two-way (red and white) reflectors should be installed on all posts, and the tops of the posts should be coated with red reflective paint. Additionally, glare protection and a tough plastic sheet should be fitted post-to-post to minimize injuries to motorcyclists. Post caps should feature 50x100mm Class 1A retro-reflective material or be placed at the front top of the post, above the wire ropes. Delineators should be spaced between 12.5 and 15 meters apart, but must not be placed on flared sections.

7.16.7.4. Measurement

The length of the completed wire rope safety barrier will be measured in linear meters, covering the supply and installation of all ropes, posts, anchorages, and fittings as specified. No additional measurement will be made for extra components beyond the end anchorages unless explicitly stated in the contract. All associated costs, including furnishing and installing anchor bolts or devices, will be included in the overall project pricing.

7.16.8. Water-Filled Plastic Movable Barriers with Reflectors

7.16.8.1. General

Water-filled barriers are modular roadside safety devices constructed from high-density polyethylene (HDPE). These barriers feature a hollow structure, allowing them to be lightweight when empty for ease of transportation and installation while providing enhanced stability and impact energy absorption when filled with water. Their durable construction ensures resistance to cracking, splitting, and weather-induced deterioration, making them suitable for various environmental conditions. Compared to rigid concrete barriers, water-filled barriers reduce impact forces on vehicles and occupants while still providing effective protection for roadside workers and infrastructure.

Water-filled barriers are used in various temporary traffic control and safety applications, including:

- Road construction and maintenance zones – To delineate work areas and protect personnel.
- Traffic control and channelization – To direct vehicular movement and provide guidance at intersections or lane closures.
- Crowd management – To establish safe perimeters at public gatherings, sporting events, and special events.
- Temporary roadblocks – To create controlled access zones for emergency response or road diversions.
- Public works projects – To establish temporary barriers for infrastructure repairs or installations.

7.16.8.2. Materials and Properties

- Barrier Material: High-Density Polyethylene (HDPE), UV stabilized for durability.
- Reflector Tape: Integrated for enhanced visibility under low-light conditions.
- Color: High-visibility colors (e.g., red, orange, white) for increased conspicuity.
- Weather Resistance: Designed to withstand temperature variations and adverse environmental conditions.
- Typical dimensions shall be:
 - Length: 1000 mm
 - Height: 800 mm
 - Width: 500 mm
 - Maximum Water Capacity: 20 liters

7.16.8.3. Construction and Installation

Water-filled barriers are designed for quick deployment and reconfiguration as required. The lightweight construction allows a two-person crew to transport and install them efficiently. Once positioned, the barriers are filled with water to increase stability. The interlocking design enables

secure connections between individual units, forming a continuous protective barrier. These barriers are particularly suited for scenarios requiring rapid response, such as emergency road closures and temporary lane adjustments.

To enhance visibility and safety, barriers are available in high-contrast colors and equipped with reflective elements to ensure visibility under various lighting and weather conditions. These features are critical in minimizing hazards for road users, particularly in work zones or areas with temporary traffic adjustments.

7.16.8.6. Measurement

The measurement for payment shall be based on linear meters of water-filled barriers installed and accepted in place. The unit rate shall include the supply, transportation, placement, filling, interlocking, and removal of the barriers as required by project specifications. No additional measurement will be made for barriers used beyond the specified work zone limits unless otherwise stated in the contract.

7.16.9. Payment

The payment shall include full compensation for furnishing of labor, materials, tools, equipment, and incidental costs necessary for doing all the work involved in constructing the crash barriers explained above, following measurement criteria, and complete in place in all respects as per these Specifications.

Pay items shall be:

Pay Items	Description	Unit
7.16.1	New Jersey Barrier	Lin. meter
7.16.2	Metal Beam/W-Beam Barrier	Lin. meter
7.16.3	Wire Rope Barrier	Lin. meter
7.16.4	Plastic Movable Barriers	Lin. meter

7.17. Guidepost

7.17.1. General

This section covers the supply, installation, and construction of guideposts, rigid or flexible, for marking the edge of the roadway, enhancing nighttime visibility, and improving alignment guidance at horizontal and vertical curves, intersections, and other roadway transitions. Guideposts with retro-reflective delineators shall be installed in pairs on both sides of the roadway to provide long-range visibility, particularly under low-light or fog-prone conditions.

Delineators shall be mounted on white guideposts with red reflectors on the left-hand side and white reflectors on the right-hand side of the carriageway, consistent with standard traffic direction. All works shall include furnishing of materials, transport, erection, alignment, and necessary fittings in accordance with the Engineering drawings or as directed by the Engineer.

This specification is aligned with best practices adapted from relevant standards, including:

- AS 1742.2 – Manual of uniform traffic control devices: Traffic control devices for general use.
- Visibility, color, and retro-reflectivity guidelines for guidepost delineation and installation in accordance with section 7.10 of this Specification.

7.17.2. Guidepost Types

Guideposts shall be selected based on their response to vehicular impact and are classified as follows:

(a) Flexible Guideposts: Fabricated from high-impact polymers such as rubber or plastic, these posts deform under impact and return to their upright position without maintenance. Standard width is 100 mm, with a white finish.

(b) Semi-Flexible Guideposts: Designed to yield upon impact but require manual realignment. Made from plastic, metal, or a combination, these posts offer intermediate durability and impact resilience.

(c) Rigid Guideposts: Made from non-timber materials such as metal or composites, these posts do not recover after impact and may remain deformed or fracture. They maintain a 100 mm width and are painted white.

7.17.3. Dimensions and Placement

Each guidepost shall stand 1,000 mm $\pm$ 50 mm above ground and maintain a width of 150-200 mm in either square or round profile. The depth of embedment shall be sufficient to ensure stability under lateral forces.

7.17.4. Siting and Alignment

- Guideposts shall be installed close to the edge of the formation and spaced uniformly, maintaining a consistent lateral distance of 1.2 to 3.0 meters from the pavement edge wherever possible.
- When road shoulders are super-elevated or uneven, guideposts shall be vertically aligned to maintain a consistent visible grade line.

7.17.5. Longitudinal Spacing

- On Straight Alignments:
 - Default spacing: 150 m, installed in symmetrical pairs on either side.
 - In fog-prone regions: spacing reduced to 75 m.
 - For low-volume roads (<1,500 vehicles/day), long straight sections, or flat curves (>2,000 m radius): spacing may be extended up to 300 m, provided at least two pairs of delineators are visible at all times.
- On Horizontal Curves:
 - Spacing shall follow the values provided in Table 7.17-1. In areas prone to fog, the spacing shall not exceed 75 m.
- On Curve Transitions:
 - Posts shall begin at the transition start (TS for transitioned curves, TC for non-transitioned curves), following the curve spacing requirements.
- In Cuttings:
 - Guideposts shall be continued throughout the full length of the cutting.
- At Crests:
 - Posts shall be positioned to ensure that at least two pairs of delineators are visible at any time, excluding those less than 40 m ahead.
 - For horizontal curves near or after crests, this requirement applies only to the outer edge of the curve.
- Bridges and Culverts

Where structures lack dedicated barriers or kerbing is located at or inside the shoulder, guideposts shall be placed as follows:

Structures ≥ 5 m in travel direction:

- Four posts minimum, one at each end of headwalls or kerbs.
- Additional pairs at intervals not exceeding 10 m for longer structures.

Structures < 5 m:

- One guidepost shall be placed at the approach end (left side) of each headwall.

If the structure's kerb or headwall lies ≥ 4 m from the traffic lane, standard roadside spacing rules apply without additional posts.

Table 7.17-1: Guidepost Spacing on Curves.

Curve Radius (R, m)	Spacing - Outside (m)	Spacing - Inside (m)
< 100	6	12
100 – 199	10	20
200 – 299	15	30
300 – 399	20	40
400 – 599	30	60
600 – 799	40	60
800 – 1,199	60	60
1,200 – 2,000	90	90
> 2,000 / Straights	150	150

Notes:

1. Radius Estimation: If not directly available, curve radius may be derived using the middle ordinate method from a known chord length.
2. Safety Barriers: Spacing may be modified to align with the placement of safety barriers.
3. Inside Placement: Inside curve guideposts should ideally align with those on the outside.
4. Fog Zones: In fog-prone areas, maximum spacing must be reduced to 75 m.
5. Formula (for reference only):
 - For curves $R \leq 150$ m: $S=0.03R+5S = 0.03R + 5S=0.03R+5$
 - For curves $150 \text{ m} < R \leq 2,000$ m: $S=0.06RS = 0.06RS=0.06R$

7.17.6. Materials

Materials for guideposts shall be selected based on the required mechanical performance, durability, and impact behavior appropriate to their classification. All guidepost types shall exhibit resistance to environmental degradation, including UV exposure, moisture, temperature variation, and physical wear.

(a) Rigid Guideposts: Rigid guideposts shall be constructed from either:

- **Precast Concrete:** Manufactured from dense, high-strength concrete with a minimum compressive strength of 25 MPa at 28 days. Units shall be factory-cast, smooth-finished, and coated white with a durable, reflective, or weather-resistant paint. Reinforcement shall be provided as per design drawings to ensure impact stability. A typical post may consist of a cylindrical unit of 150 mm diameter and 1.5 m length, embedded as shown in the Engineering drawings.
- **Steel:** Shall be flanged channel section posts, weighing no less than 1.67 kg/m before galvanization, and fabricated from structural steel with a minimum tensile strength of 345 MPa and a yield strength of 250 MPa. Elongation shall not be less than 5% over a 50 mm gauge length. All holes and fabrication shall be completed before hot-dip galvanizing in accordance with AASHTO M 111 (equivalent to ASTM A123). The final finish shall be white and uniform.

(b) Flexible Guideposts: Flexible posts shall be made from high-impact polymeric materials such as:

- UV-stabilized polyethylene (HDPE), polypropylene, polyvinyl chloride (PVC), or equivalent thermoplastics.
- Posts must be capable of returning to vertical orientation after being deflected by vehicular impact at speeds up to 100 km/h without the need for maintenance.
- Flexible guideposts shall be white and fitted with wraparound high-intensity retro-reflective bands (minimum 75 mm width) meeting ASTM D4956 Type III or higher.
- Alternatively, reflex reflectors made of hermetically sealed acrylic plastic (approximately 75 mm diameter), mounted in embossed aluminum with a single grommet hole, may be used, subject to the Engineer's approval.

(c) Semi-Flexible Guideposts: These shall be made from composite materials such as elastomer-coated metal or impact-resistant plastics, designed to bend under impact and be manually restorable without cracking or permanent deformation. Material selection shall prioritize fatigue resistance and long-term resilience under repeated loading.

(d) Timber Guideposts: Timber posts shall be constructed from structurally sound hardwood or softwood that has been kiln-dried and pressure-treated with approved preservatives to resist rot, insect attack, and weathering. The timber surface shall be finished with white exterior-grade protective paint.

(e) Reflective Delineators (All Types): All guideposts shall be fitted with high-intensity retro-reflective sheeting or panels compliant with ASTM D4956 (minimum Type III) or EN 12899-1 standards. Color schemes shall be followed as specified in the Delineator section of this Specification.

7.17.7. Construction and Installation

The installation of guideposts shall be carried out in accordance with the approved Engineering drawings and alignment requirements specified by the Engineer. Posts shall be set vertically at a uniform offset from the pavement edge, typically between 1.2 m and 3.0 m, unless otherwise directed. Care shall be taken to ensure consistent height above ground ($1,000 \pm 50$ mm) and proper alignment in both straight and curved sections.

Rigid concrete guideposts shall be installed using a footing-type base to ensure structural stability and long-term durability. The footing shall consist of a square or circular concrete base with a minimum plan dimension of 250 mm and a depth of not less than 500 mm, depending on soil bearing capacity and post height. The post shall be centrally positioned within the footing and held plumb during casting. Concrete used for the footing shall be of minimum Class B (15 MPa) or as specified in the Engineering drawings. Proper curing shall be ensured before subjecting the post to external loads. In cohesive soils or soft subgrades, extended depth or wider footings may be required as directed by the Engineer.

For rigid and timber posts, excavation or boring shall be done to the specified depth to ensure stability, and the posts shall be embedded firmly in compacted backfill or concrete as required. Flexible and semi-flexible posts may be installed using ground sockets, drivable anchors, or approved surface mounting systems, depending on the product type and surface conditions.

All posts shall be installed without damage, and reflective delineators shall be affixed at the specified height and orientation for maximum visibility. Any damaged or misaligned posts shall be removed and replaced at the Contractor's expense.

7.17.8. Measurement

Guideposts shall be measured by the actual number of units installed, completed, and accepted at the site in accordance with the Engineering drawings and Specifications. The measurement shall include all operations related to placement, including excavation, foundation construction (where required), installation of ground sockets, drivable anchors, or approved surface-mount systems, post erection, backfilling, alignment, and associated fittings, but shall exclude delineator reflectors, which shall be measured and paid for separately.

7.17.9. Payment

Payment for guideposts shall be made at the contract unit rate per number of posts installed. The unit rate shall constitute full compensation for all materials, labor, equipment, transportation, handling, excavation, foundation or anchoring systems, backfilling, alignment, and other incidentals necessary to complete the work in accordance with the Engineering drawings, Specifications, and direction of the Engineer.

Pay items shall be:

Pay Items	Description	Unit
7.17.1	Rigid or concrete guidepost	Number
7.17.2	Semi-rigid guidepost	Number
7.17.3	Flexible guidepost	Number
7.17.4	Timber guidepost	Number

7.18. Fencing for Footpath / NMT Lane Separator

7.18.1. General

This section covers the supply, fabrication, delivery, and installation of mild steel bar-type fencing systems to be installed along footpaths, non-motorized traffic (NMT) lane separators, road medians, or other designated boundaries, as shown in the contract drawings or as directed by the Engineer. The

fencing shall serve both protective and segregation functions while meeting aesthetic, structural, and safety requirements.

The specifications outlined herein are adapted and harmonized with the provisions of BS 1722-9:2006. Accordingly, the fencing shall be fabricated using vertical steel bars (round, square, or square-angle) welded to flat horizontal rails/rectangular hollow section and supported by structural posts. The entire assembly shall be mounted on properly constructed reinforced concrete footings, aligned both vertically and longitudinally to match the finished site profile.

All steel components shall be fabricated using pre-approved materials, and protected against corrosion in compliance with Section 7.1.2.5: Preservatives, Paints and Finishes for Posts and Fittings of this Specification. The installation shall be completed in all respects to the satisfaction of the Engineer.

The Contractor shall ensure that the completed fencing system:

- Complies with all dimensional, material, and mechanical requirements of this Specification;
- Withstands environmental exposure, impact loading, and potential vandalism;
- Provides clear demarcation, maintains visual uniformity, and contributes to overall site safety.

Fencing systems shall be chosen based on functional need, environmental exposure, visual compatibility, and specific site requirements. Illustrative diagrams, component identification, and dimensional configuration tables are included under the respective subsections of this Specification to aid in implementation and inspection.

7.18.2. Mild Steel Fencing with Round or Square Verticals and Flat Horizontals

7.18.2.1 Typical Fence Configurations and Component Identification

This item includes the fabrication, supply, and installation of fencing composed of mild steel vertical bars (round or square) welded to flat horizontal members, installed over reinforced concrete foundations. Fencing top may be constructed in the following configurations:

- Bow Top Fences: Feature vertical round bars with smoothly curved (bowed) tops that loop over to rejoin the top horizontal rail. These are often used for aesthetic appeal and public safety, particularly in parks, schools, and pedestrian areas, as they eliminate sharp edges.
- Square-to-View Fences: Constructed with square vertical bars oriented so that one flat face is visible from the front. The top ends of these bars may be finished with blunt, domed, or pointed profiles. This configuration provides a traditional appearance with options for security enhancement.

- **Angle-to-View Fences:** Also use square vertical bars, but the bars are rotated 45 degrees so that a corner faces outward (diagonal presentation). This orientation enhances visual deterrence, provides greater rigidity, and increases resistance to climbing or deformation under impact.

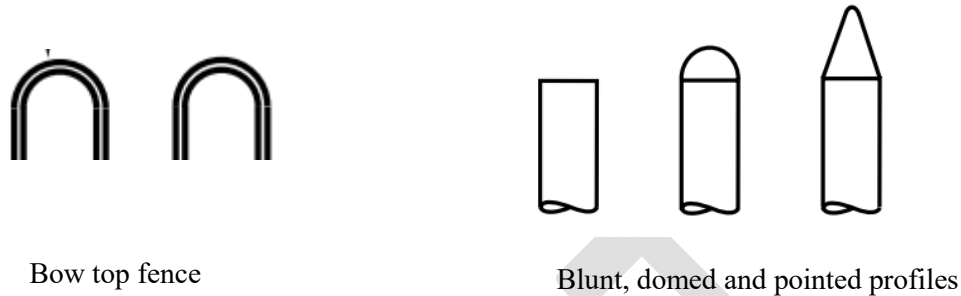
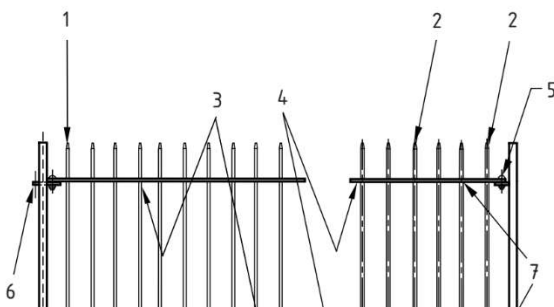
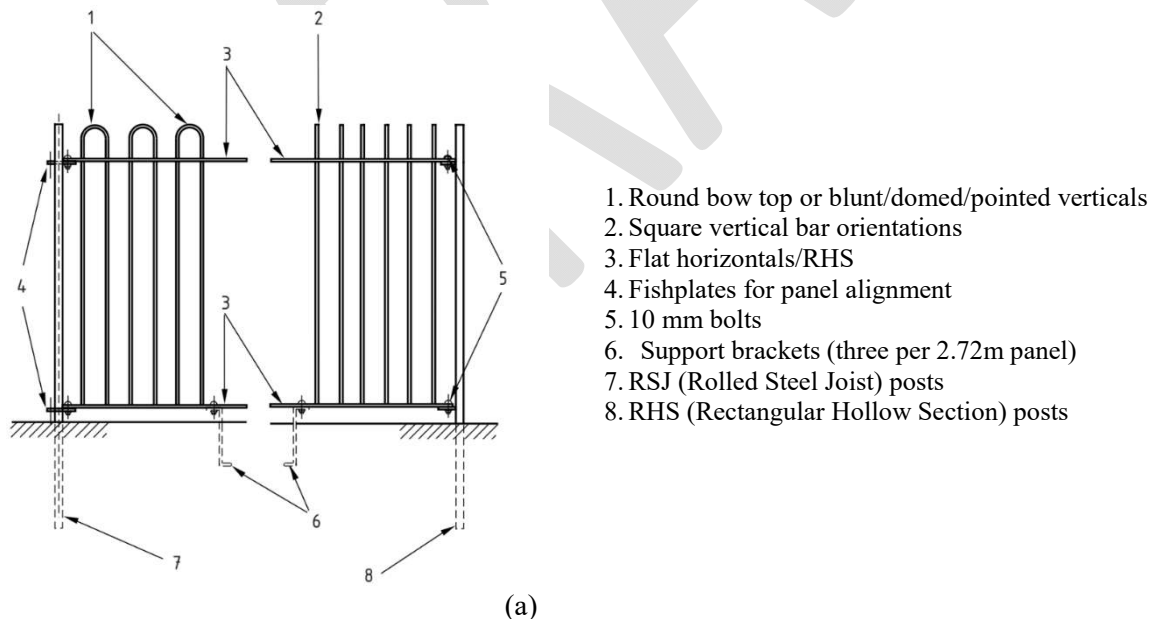


Figure 7.18-1: Configurations of fencing top.

Figure 7.18-2 illustrates the fence types, showing bar orientation, post types, supports, fishplates, and top profiles.

This subsection includes schematic diagrams from BS 1722-9:2006 showing:

- (a) Bow top and round verticals with flat horizontals
- (b) Square-to-view and angle-to-view self-adjusting verticals



1. Round bow top or blunt/domed/pointed verticals
2. Angled vertical bar orientations
3. Mechanically formed nibs
4. Flat horizontals/RHS
5. 10 mm bolts
6. Fishplates
7. Mechanically formed nibs above and below horizontals
8. Permanent fixing
9. Support brackets (three per 2.72m panel)
10. RSJ (Rolled Steel Joist) posts
11. RHS (Rectangular Hollow Section) posts

(b)

Figure 7.18-2: Typical Fence Configurations and Component Identification.

7.8.2.2. Dimensional Requirements

Tables 7.18-1 to 7.18-3 define the dimensional standards based on fence height and bar type, simplified from BS 1722-9:2006:

Table 7.18-1: Bow Top Fences (Round Bars)

Height (m)	Post Embed (mm)	Vertical Bar Dia./Dimension of square bar (mm)	Vertical Bar Spacing (mm)	Number of Verticals/2.72 m Panel	Size of Horizontal Bars/RHS (mm)	RSJ Post (mm)	RHS Post (mm)
0.60–1.00	450	10	79	34	30×6 / 30×15×3	—	50×50×5
1.00–1.20	550	12	112	24	30×10/ 30×20×3	102×44	75×75×5
1.20–1.40	550	16	112	24	40×10/ 40×20×3	102×44	75×75×5
1.20–2.40	600	20–22	120	22	50×10/ 50×25×3	102×44	80×80×5

Note A: Only welded construction permitted. Post spacing is 2.72 m standard. Spacing refers to the center-to-center distance of verticals.

Table 7.18-2: Square Bar Fences (Flat Face to View)

Height (m)	Post Embed (mm)	Vertical Bar Dia./Dimension of square bar (mm)	Vertical Bar Spacing (mm)	Number of Verticals/2.72m Panel	Size of Horizontal Bars/RHS (mm)	RSJ Post (mm)	RHS Post (mm)
1.00–1.20	550	12 / 16	112	24	40×10/ 40×20×3	102×4 4	50×50× 5
1.20–2.40	600	20 / 22	120	22	50×10/ 50×25×3	102×4 4	80×80× 5

Note B: Verticals with a flat face presented to the front. Bar size below 16 mm is not recommended for mechanical nibbing.

Table 7.18-3: Square Bar Fences (Angle to View)

Height (m)	Post Embed (mm)	Vertical Bar Dia./Dimension of square bar (mm)	Vertical Bar Spacing (mm)	Number of Verticals/2.72m Panel	Size of Horizontal Bars/RHS (mm)	RSJ Post (mm)	RHS Post (mm)
1.00–1.20	550	12 / 16	116 / 120	22–23	40×10/ 40×20×3	102×4 4	50×50× 5
1.20–2.40	600	20 / 22	125–130	21	50×10/ 50×25×3	102×4 4	80×80× 5

Note C: Square bars presented at an angle (corner outward). Provides increased rigidity and impact resistance.

7.18.2.3. Materials and Components

The materials used for the fabrication of mild steel bar-type fences shall conform to recognized structural steel and fabrication standards. The components shall include the following:

Structural Steel Grade: The fencing system shall be fabricated using structural-grade mild steel conforming to ASTM A36/A36M. This specification covers carbon steel shapes, plates, and bars of structural quality for use in riveted, bolted, or welded construction. ASTM A36 steel provides a minimum yield strength of 250 MPa (36,000 psi), ensuring reliable structural performance and excellent weldability. Its toughness and ductility make it suitable for general outdoor applications, including roadside and footpath fencing.

Vertical Bars: Vertical members may be manufactured using round bars, square bars, or square bars set at an angle to view, based on the selected fence configuration (e.g., bow top, square-to-view, or angle-to-view). The choice of bar type shall be guided by both aesthetic and structural considerations. Bar sizes and spacing shall conform to the dimensional tables provided in this specification. Where

mechanical nibbing is utilized, bar diameter and spacing shall meet the necessary structural performance criteria.

Horizontal Members: The horizontal members shall be fabricated from either flat steel bars or rectangular hollow sections (RHS), depending on the fence type and structural requirements. These members shall serve to rigidly bind and stabilize the vertical bars at the top and bottom of each panel. For flat bar construction, typical dimensions range from 30×6 mm to 50×10 mm. Where RHS members are used, standard sizes include 30×15×3 mm, 40×20×3 mm, and 50×25×3 mm, selected based on the panel height and expected loading. All horizontal members shall be fabricated from the same structural-grade mild steel as the verticals to ensure uniform mechanical properties, strength, and weldability.

Fence Posts: Fence panels shall be mounted on structural posts made from either RSJ (Rolled Steel Joist) sections or RHS (Rectangular Hollow Section) steel. RSJs are I-beam-shaped hot-rolled members with high bending strength, often used where additional lateral rigidity is needed. RHS posts, on the other hand, are clean-profile hollow rectangular or square steel tubes, preferred for their modern appearance and ease of fabrication. RSJ sections shall conform to BS EN 10025-2, while RHS members shall meet the requirements of BS EN 10210-2 for hot-finished hollow sections or BS EN 10219-1 for cold-formed sections, as appropriate.

Welding Requirements: Vertical bars shall be securely welded to the flat horizontal bars, with welds extending around a minimum of 50% of the bar perimeter. Welds may be continuous or intermittent, depending on the design, and shall be executed by qualified personnel using approved welding methods. Exposed welds shall be ground smooth where required to ensure a safe, tamper-resistant, and aesthetically acceptable finish.

Fixing Accessories and Fasteners: All required fixing components, including fishplates, support brackets, and galvanized steel bolts (typically 10 mm diameter), shall be provided for secure panel-to-post connection and lateral bracing where needed. These components shall be fabricated from galvanized steel or stainless steel, and shall conform to the corrosion protection standards described in Section 7.1.2.5 – Preservatives, Paints and Finishes for Posts and Fittings.

Protective Treatment: All steel members shall conform to the corrosion protection standards described in Section 7.1.2.5: Preservatives, Paints and Finishes for Posts and Fittings, of this Specification.

7.18.2.4. Installation

a) Foundations and Concrete Specification:

Fence posts shall be embedded in cast-in-situ concrete footings, with minimum dimensions and depths as defined in Tables 7.18-1 to 7.18-3 of this Specification, depending on the height and configuration of the fence.

- The footing size shall be a minimum of 300 mm × 300 mm in plan and 500 mm in depth, unless otherwise specified. However, the embedment length of posts, as specified in Tables 7.18-1 to 7.18-3, shall govern the final foundation depth requirement. If the required embedment exceeds the standard depth, the footing shall be adjusted accordingly to accommodate the necessary post insertion depth.
- The concrete mix shall conform to ASTM C94/C94M for ready-mixed concrete or be composed of a nominal mix of 1 part Portland cement to 10 parts 20 mm ($\frac{3}{4}$ inch) all-in aggregate, using materials that comply with ASTM C150 for cement, ASTM C33 for aggregates, and ASTM C143/C143M for slump control. For structural post foundations, the concrete shall achieve a minimum 28-day compressive strength of 20 MPa (≈ 3000 psi).
- Clean water shall be used, and concrete shall be placed before the onset of initial set.
- A minimum concrete cover of 50 mm shall be provided on all sides of the post to protect against corrosion and impact.
- For ground-mounted fencing, footings shall allow secure embedment as specified in the dimensional tables.

b) Post Installation and Finishing:

- Posts shall be set true to line and plumb, spaced to suit the standard 2.72 m fence panel width, and shall be topped with protective end caps to prevent water ingress and rust formation.
- Post types and sizes shall comply with the dimensional tables (RSJ or RHS section as applicable).
- Concrete around posts shall be adequately compacted and cured before load application or further installation.

c) Panel Fixing and Horizontal Placement:

- Fence panels shall be attached to posts using galvanized steel fishplates, cleats, or bolted brackets with a minimum 10 mm diameter galvanized bolts.
- Alternatively, panels may be welded directly to posts. All welds and any areas of damaged galvanizing shall be cleaned and coated with zinc-rich paint or repair compounds conforming to ASTM A780 (Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings), to restore corrosion protection equivalent to the surrounding galvanized surfaces.
- Horizontals shall be joined at post locations, and the upper horizontal member shall be located based on the total fence height:

- 130 mm $\pm$ 5 mm from the top for fences up to 1.00 m;
- 150 mm $\pm$ 5 mm for fences over 1.00 m and up to 1.50 m;
- 200 mm $\pm$ 5 mm for fences over 1.50 m.
- The bottom edge of the fence panel shall maintain an average ground clearance of 75 mm $\pm$ 5 mm.

d) Vertical Bar Integration:

- In welded fence panels, vertical bars shall pass through holes in the horizontal members and be welded at both top and bottom ends, with a weld length not less than 50% of the perimeter of each bar.
- In self-adjusting panels, verticals shall be passed through the horizontals and secured by mechanically formed nibs or equivalent permanent fixings. These verticals shall extend 75 mm below the bottom horizontal to ensure secure seating.

e) Support Arrangement:

- Ground-mounted supports shall be made from flat bar steel, with cross-sections not more than 10 mm smaller than the horizontal (e.g., 40 $\times$ 10 mm for a 50 $\times$ 10 mm horizontal). Supports shall be bent at two 90° angles (Z-shaped), 50 mm $\pm$ 5 mm from each end, and embedded at least 200 mm into the ground.
- For fences fixed atop concrete or brick walls, the following support types may be used:
 - L-shaped flat supports, 175–250 mm in length, bent 50 mm $\pm$ 5 mm from one end for grouting into preformed pockets;
 - Threaded round bars matching the vertical bar section, secured with two nuts.

f) Support Spacing:

- For welded bar fencing, supports shall be spaced as close as practicable to 910 mm $\pm$ 5 mm along the panel, and from each end post.
- For self-adjusting vertical fencing, supports shall be spaced 700 mm $\pm$ 5 mm along the panel and from the ends.
- Supports must be securely fixed to the bottom horizontal rail to resist movement.

g) Renovation of Coatings after Installation:

Any galvanized coatings that are damaged during fabrication, transport, welding, cutting, or erection shall be repaired in accordance with ASTM A780 (Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings). Approved methods include the application of zinc-rich paints, soldering, or zinc thermal spray. The repaired area shall be prepared and coated to achieve

a minimum dry film thickness equal to that of the surrounding galvanizing, and shall restore full corrosion protection in both appearance and performance.

h) Final Adjustments and Quality Checks:

- Once the concrete has adequately cured, all installed components shall be checked for alignment, verticality, spacing uniformity, and fastener security.
- Any deviations shall be corrected, and all surfaces shall be inspected for coating integrity and overall finish before the fencing is approved by the Engineer.

7.18.2.5. Testing Requirements

Testing requirements for steel grade, welding, galvanization, paint coating, and fasteners are covered in their respective sections of this Specification. In addition, the Contractor shall verify dimensional compliance, including bar spacing, embedment depth, and alignment, against approved Engineering drawings and Tables 7.18-1 to 7.18-3. All components shall be measured using calibrated tools, and installation shall be inspected for plumb, level, and secure anchorage. Final approval shall be subject to the Engineer's satisfaction following inspection.

7.18.4. Measurement

Fencing for footpaths, non-motorized traffic (NMT) lane separators, road medians, or other designated boundaries shall be measured in linear meters, based on the actual length constructed and accepted at the site. Measurement shall be taken along the centerline at the top of the fence, in accordance with the alignment, dimensions, and details shown on the approved Engineering drawings or as directed by the Engineer. The measured length shall include all components of the fencing system, including posts, bars, footings, fittings, galvanizing, and painting. No deductions shall be made for intermediate elements or embedded parts, and no separate measurement shall be made for excavation, backfilling, or surface restoration (reinstatement or repair work done to paved or finished surfaces (e.g., footpaths, NMT lanes, road shoulders) that are disturbed during fencing installation).

7.18.5. Payment

Payment shall be made at the contract unit rate per linear meter, which shall be full compensation for all materials, labor, equipment, fabrication, transport, installation, alignment, coating, excavation, concrete footings, backfilling, site restoration, and all other incidentals necessary to complete the fencing work in accordance with the Engineering drawings and specifications. No separate payment shall be made for curing, coating, repairs, or adjustments due to handling or erection.

Pay items shall be:

Pay Items	Description	Unit
7.18.1	Fencing for footpaths, non-motorized traffic (NMT) lane separators, road medians, or other designated boundaries	Lin. meter
(a)	height 0.6m -1.0m	
(b)	height 1.0m -1.2m	
(c)	height 1.2m -1.4m	
(d)	height 1.4m -2.4m	

7.19. Traffic Calming Devices: Speed Table and Speed Hump

7.19.1. General

This section covers the construction of Speed Tables and Speed Humps as engineered traffic calming devices, intended to reduce vehicular speeds and enhance roadway safety in designated environments. These devices are especially recommended for application in areas with significant pedestrian movement, such as bazars, school zones, college or university precincts, health facility frontages, and other critical crossing locations identified through road safety assessments. These devices function through vertical deflection of the roadway, compelling drivers to reduce speed while maintaining continuous traffic flow. Their deployment aims to:

- Improve driver attentiveness and pedestrian visibility;
- Enforce localized speed reduction in conflict-prone zones;
- Enhance pedestrian crossing conditions;
- Reduce crash severity in populated or vulnerable road segments.

Raised pedestrian crossings may be integrated on top of speed tables, where appropriate, to support safer crossing movements in areas with high pedestrian demand and existing footpath connectivity.

Speed Tables, Speed Humps, and Raised Pedestrian Crossings shall be accompanied by appropriate traffic signs, advance warning signs, and pavement markings in accordance with the provisions of the RHD Road Safety Engineering Manual, 2024, and the BRTA Traffic Signs Manual.

All design, material selection, geometric dimensions, and construction practices for Speed Tables and Speed Humps shall comply with this Specification and be carried out under the supervision and satisfaction of the Engineer. The RHD Road Safety Engineering Manual 2024 shall be referred to for contextual guidance on location selection, design criteria, spacing intervals, and prioritization of traffic calming measures using Speed Tables or Speed Humps within the broader road safety improvement framework.

Physical devices to calm speed

To achieve effective speed reduction in areas with high pedestrian activity, the installation of physical traffic calming devices such as Speed Table or Speed Humps is essential in addition to conventional signage. Average drivers often ignore traffic signs, such as speed limit signs, unless the necessity for those signs is immediately apparent. This is particularly necessary on recently rehabilitated roads where drivers tend to disregard traffic signs and adopt higher speeds unless physical deterrents are present.

Speed Table

A Speed Table is a trapezoidal raised platform over an extended width with a flat top and sloped ramps on both ends. It is designed to accommodate moderate vehicle speeds (30–60 km/h). Speed tables are particularly effective in urban or semi-urban areas where continuous traffic movement is needed, but at reduced speed.

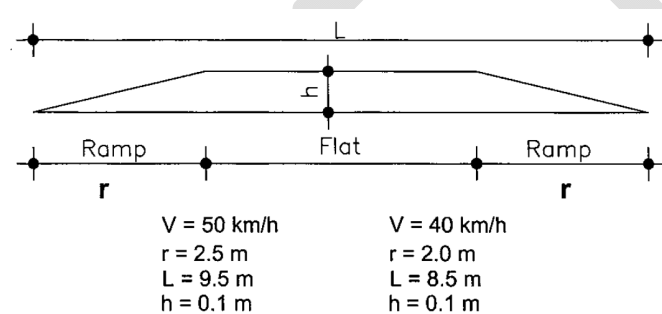


Figure 7.19-1: Speed Table dimensions.

Speed tables can also incorporate Raised Pedestrian Crossings on their flat tops, making them dual-purpose installations. The integrated crossing facilitates safe pedestrian movement across roads and is commonly applied where there are continuous footpaths on both sides of the carriageway and pedestrian volumes are significant. Typical pedestrian crossing widths range from 3.0 m to 5.0 m. The following options may be considered for integrating pedestrian crossing marking with speed tables:

- On speed tables: Where traffic flow is heavy and speed is around 30km/h, pedestrian crossings on speed tables are particularly attractive if there is already a footpath.
- Between speed tables: Where traffic flow is heavy and speed is around 40 to 50km/h, pedestrian crossings may be located between speed tables.
- May be excluded: Where traffic flow is moderate and speed is low with busy pedestrian activities, pedestrian crossings may not be required.

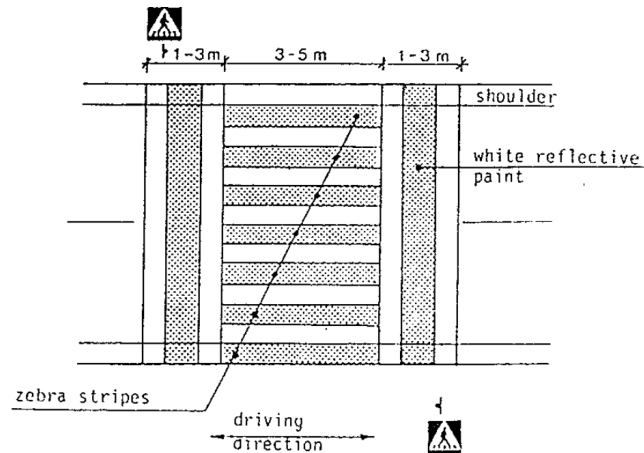


Figure 7.19-2: Raised pedestrian crossing with speed table. (See the details of raised pedestrian marking from the RHD Road Safety Engineering Manual 2024)

Speed Hump

A Speed Hump is a rounded or sinusoidal vertical deflection placed over an extended width at a perpendicular direction to the traffic flow. It is narrower in length compared to a speed table and is typically used to enforce lower vehicular speeds (20–40 km/h) over short distances, often in residential or low-speed environments.

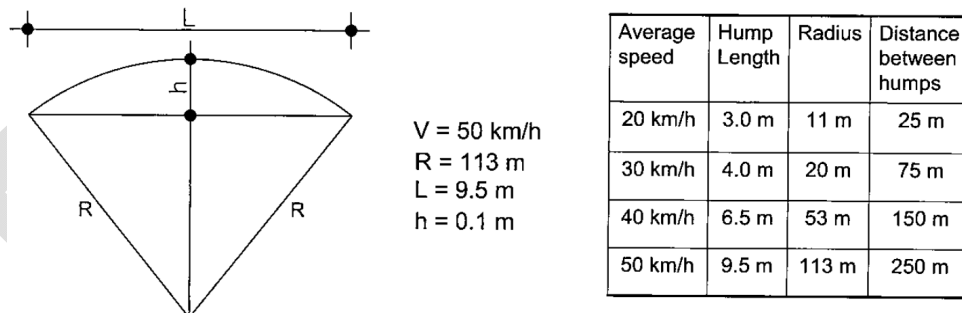


Figure 7.19-3: Speed Hump dimensions.

Unlike speed tables, speed humps are not recommended to be integrated with pedestrian crossings, as their geometry is not conducive to comfortable pedestrian passage.

7.19.2. Materials

7.19.2.1. Tack Coat/Bonding Coat

The tack coat shall consist of rapid-curing type cutback bitumen, either RC-2 or RC-4, and shall conform to **Sub-Clause 4.4.2** of this Specification. The tack coat shall be applied to existing bituminous

surfaces at locations designated for Speed Table or Speed Hump, ensuring a strong bond with the overlaying layer.

Where the base pavement is concrete, an approved bonding agent compatible with the concrete surface and bituminous overlay shall be used in lieu of a conventional tack coat (e.g., polymer-modified bituminous emulsion, bitumen rubber emulsion, or epoxy-based bonding compound).

7.19.2.2. Bituminous Mixture

The bituminous material for the construction of Speed Table or Speed Hump shall be Premix Bituminous Carpeting (PBC), complying with the requirements of **Clause 4.5** of this Specification. The mixture shall include 3% Ordinary Portland Cement (OPC) as filler to enhance cohesion and strength.

For the sloped ramp sections of speed tables or speed humps, a fine-graded bituminous mixture with a reduced nominal maximum aggregate size (typically not exceeding 10 mm) shall be used. The mix shall provide a smooth transition, adequate workability, and proper compaction at thin tapering layers. The mixture shall conform to the same performance requirements as the main bituminous material, but with adjusted grading as approved by the Engineer.

7.19.2.3. Formwork

Steel forms shall be used to define the shape and dimensions of the Speed Table or Speed Hump as per approved Engineering drawings. Forms shall be secured firmly to the road surface to prevent leakage or deformation during placement and compaction.

7.19.3. Construction Methods

7.19.3.1. Surface Preparation

The existing bituminous pavement shall be thoroughly cleaned of all loose particles, dust, grease, deleterious substances, and other foreign substances which, in the opinion of the Engineer, would prevent proper bonding of the tack coat. Where required, light chipping of the surface shall be performed to enhance bonding, subject to approval by the Engineer.

On concrete surfaces, surface laitance shall be removed by mechanical scarifying or bush hammering to expose coarse aggregates. The surface shall then be cleaned thoroughly and kept dry prior to application of the bonding coat. All existing cracks and joints in the concrete surface shall be cleaned and sealed using a flexible bituminous sealant or crack repair system, as approved by the Engineer, to prevent reflective cracking and water ingress.

7.19.3.2. Application of Tack Coat/Bonding Coat

Immediately after the surface has been cleaned and approved by the Engineer, the tack coat shall be applied to the area of construction where premix bituminous material shall be applied on the existing bituminous surface. The bituminous material shall be applied by means of approved hand-spraying equipment. The rate of application shall be as shown on the plans or as ordered by the engineer, but in no case shall it exceed 0.25 liter per square meter. The tack coat shall be applied uniformly and to the satisfaction of the Engineer.

On a concrete surface, a compatible bonding agent such as a polymer-modified bituminous emulsion or epoxy-based bonding compound shall be applied in accordance with manufacturer recommendations and as approved by the Engineer. The bonding coat shall ensure strong adhesion between the concrete substrate and the bituminous overlay.

7.19.3.3. Placing of Bituminous Mixture

Once the tack coat has set, the hot bituminous mixture shall be placed within the prepared formwork and compacted using approved hand tools. The surface shall be struck off flush with the top of the forms to ensure uniform level.

The sloped sections shall be constructed using the fine-graded mix in a tapered profile, feathered carefully to match the existing pavement level. Cold joints or abrupt steps shall not be permitted.

7.19.3.4. Compaction

After placement, the formwork shall be carefully removed, and rolling shall commence immediately using a pneumatic-tyred or vibratory roller as directed by the Engineer. Rolling shall be continued until the required compaction is achieved. Turning the roller or static roller on the work surface shall not be permitted. Any excess tack coat visible after compaction shall be blotted using clean, dry sand.

7.19.3.5. Signage and Road Markings

Pre-warning traffic signs shall be installed in both directions in advance of the first crossing location of the speed table, Speed Hump, or Raised Pedestrian Crossing, in accordance with the requirements of the RHD Road Safety Engineering Manual 2024. In addition, Speed table or Speed Hump or Raised Pedestrian Crossing shall be marked with appropriate thermoplastic pavement markings to ensure visibility during night-time and low-visibility conditions, in accordance with the requirements of the RHD Road Safety Engineering Manual 2024.

The construction of Speed Tables, Speed Humps, or Raised Pedestrian Crossings shall be considered incomplete without the installation of corresponding traffic signage and pavement markings.

7.19.4. Measurement

Speed Table and Speed Hump shall be measured by their volume in cubic meters, based on the actual dimensions constructed, completed, and accepted by the Engineer in accordance with the Engineering drawings and this Specification.

Bituminous tack coat (used on bituminous pavement) and bonding agents (used on concrete pavement), including polymer-modified bituminous emulsion, bitumen rubber emulsion, or epoxy-based bonding compound, shall be measured separately in square meters, based on the actual area treated, in accordance with Item 3.7.1 or as specified elsewhere in the RHD Technical Specifications.

Traffic signs and thermoplastic pavement markings associated with Speed Tables, Speed Humps, or Raised Pedestrian Crossings shall be measured and paid under their respective items as per Section 7.1 (Traffic Signs) and Section 7.3 (Road Markings) of these Specifications, unless otherwise specified.

No separate measurement shall be made for formwork, surface preparation, tack coat/bonding agent, crack or joint sealing, or for the use of different aggregate gradation for sloped sections; these shall be considered incidental to the respective pay items.

7.19.5. Payment

Payment shall be made under the respective contract unit rates and shall constitute full compensation for the supply and installation of all materials, including bituminous mixture, cement filler, and tack coat or bonding agent; surface preparation, including scarifying, cleaning, and sealing of cracks or joints where applicable; provision and removal of formwork; placement, shaping, and compaction of bituminous layers; construction of sloped ramp sections using fine-graded mixture; and for all labor, equipment, tools, transportation, and incidental works necessary to complete the item in accordance with this Specification.

Pay items shall be:

Pay Items	Description	Unit
7.19.1	Speed Table or Speed Hump on Bituminous Surface	Cu. meter
7.19.2	Speed Table or Speed Hump on Concrete Surface	Cu. meter
3.7.1	Bituminous Tack Coat	Sq. meter
7.19.3	Polymer-modified bituminous emulsion/ Bitumen rubber emulsion/Epoxy-based bonding compound	Sq. meter

7.20. Median Rumble Strips

7.20.1. General

This section covers the construction of transverse rumble strips, also referred to as median rumble strips, which are installed across the carriageway to function as driver alert systems in advance of potentially hazardous locations. These devices are designed to generate a combination of auditory and tactile feedback in the form of a rumbling sound and vibration when a vehicle passes over them, prompting drivers to regain attention and recognize the need to decelerate.

These devices are typically applied on approaches to intersections, pedestrian crossings, roundabouts, urbanized sections, toll plazas, tunnels, and sharp horizontal curves, especially in free-flow sections of rural or high-speed roads. Their effectiveness is maximized when used in conjunction with appropriate regulatory or warning signage, unless the hazard is considered self-explanatory by design or environment.

Rumble strips are also useful where drivers may become inattentive after extended periods of uninterrupted driving, a condition commonly referred to as “speed blindness.” The primary purpose of rumble strips is not to reduce speed through vertical deflection, but rather to increase driver awareness and attentiveness. They act as sensory warning cues, alerting drivers to the presence of upcoming hazards.

The design, placement, and dimensional standards for rumble strips shall conform to the provisions of the RHD Road Safety Engineering Manual, 2024, be implemented in accordance with the approved Engineering drawings and site-specific requirements, and be in compliance with this Specification

7.20.2. Rumble Strip Configuration

Rumble strips shall be constructed in sets. Each rumble strip set shall typically consist of 6 to 15 transverse bars, each 300 mm in width, placed across the full width of the carriageway. The maximum height of each bar shall not exceed 12 mm, and the markings shall be applied in two thermoplastic layers as illustrated in Figure 7.20-1. Bars within a single set shall be spaced at 600 mm intervals, measured from leading edge to leading edge.

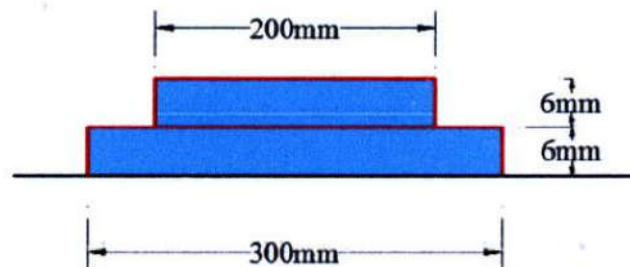


Figure 7.20-1: Rumble strip configuration using thermoplastic paints. (Source: RHD Road Safety technical Instructions)

The number of sets and the distance from the target hazard or obstruction (L) shall depend on the design speed of the approach section. The clear distance (L1) between successive rumble strip sets and the number of sets required shall be as specified in Table 7.20-1. Additionally, the number of bars in each set may be progressively increased within the 6 to 15 range based on local site conditions, including traffic volume, pedestrian demand, and frequency of cross-traffic.

Table 7.20-1: Rumble Strip Configuration Based on Speed Limit

Speed Limit (km/h)	Distance from Obstruction (L) (m)	Clear Distance Between Sets (L1) (m)	No. of Sets
40	100	25	1 Set
50	125	30	2 Sets
60	150	35	2 Sets
70	175	40	3 Sets
80	200	45	3 Sets
>80	225 or as directed	50 or as directed	4 or more Sets

The design and spacing of rumble strips shall be site-specific and are subject to the approval of the Engineer. The Contractor shall submit detailed layout drawings of the proposed rumble strip configuration, including the number of sets, bar spacing, and distances from the point of hazard, for review and approval prior to commencement of works. The Engineer reserves the right to modify the spacing, number of strips, or overall layout based on actual site conditions and safety requirements.

The construction of rumble strips using bituminous material or with dimensions not specified in this Specification or the approved Engineering drawings shall be strictly prohibited.

7.20.3. Material

Same as 7.3.1 from this specification

7.20.4. Measurement

Same as 7.3.6 from this specification

7.20.5. Payment

Same as 7.3.7 from this specification

7.21. Convex Mirror

7.21.1. General

This work shall consist of the supply, delivery, and installation of convex mirrors at designated locations to improve visibility and enhance traffic safety, particularly in areas with restricted sight distance. The convex mirror, also referred to as a spherical or wide-angle mirror, shall provide an extended field of view for drivers to detect oncoming vehicles, pedestrians, or other road users in advance, thereby reducing the likelihood of conflicts or accidents.

Convex mirrors shall be installed in accordance with the approved Engineering drawings or as directed by the Engineer, and are intended for use in low-speed vehicle and pedestrian interaction zones. All works under this item shall be carried out in compliance with the provisions of this Specification and the RHD Road Safety Engineering Manual, 2024.

7.21.2. Optical Properties and Considerations

Convex mirrors are designed to enhance driver visibility by revealing vehicles or pedestrians that would otherwise be obscured, particularly at conflict points. To achieve a wide field of view, the mirror must have a convex surface; however, this introduces image distortion.

The extent of distortion is influenced by the radius of curvature; a smaller radius increases distortion, making objects appear smaller, farther away, and slower than they actually are. This may limit a driver's ability to accurately interpret distance and speed. Conversely, a larger radius reduces distortion but narrows the field of view.

Convex mirrors also cause lateral inversion, meaning objects are mirrored from left to right. This can confuse road users, particularly in interpreting the correct lane position of oncoming vehicles.

While convex mirrors are effective at night, especially for detecting approaching headlights, their clarity may be reduced in environments with multiple light sources. Additionally, dark-colored vehicles (e.g., black or dark blue) may be harder to detect in low-angle light conditions such as early morning or late afternoon, due to low contrast against the pavement background.

7.21.3. Application Guidelines and Precautions

Convex mirrors may be considered in the following scenarios:

1. **At access points to the road network**, such as:
 - Concealed or recessed driveways;
 - Property exits with obstructed views of the main road;
 - Parking areas with acute-angle exit driveways;
 - Side roads or minor road connections, particularly where they join main roads at sharp angles, on curves, or without adequate geometric design.
2. **Within the road network**, particularly at locations where lateral visibility is restricted, including:
 - Obscured or skewed T-junctions and intersections;
 - Sharp curves and blind corners, including hairpin bends on narrow or mountainous roads;
 - Single-lane Road sections with two-way traffic, where advance visibility is essential;
 - Approaches to skewed railway level crossings;
 - Exit ramps from underpasses or walled structures with poor driver visibility;
 - Loading areas or internal facility roads with limited line-of-sight for vehicles or pedestrians.

Precautionary Limitations

Convex mirrors shall not be considered a default solution and should only be installed as a traffic safety device if there is a severe problem with sight distance and there are no other viable options available. The following precautions are necessary:

- They should only be used in low-speed, low-volume environments, typically where the 85th percentile speed does not exceed 60 km/h.
- Mirrors should not be used to facilitate pedestrian crossings, as they may not provide adequate visibility or response time. Alternative treatments such as pedestrian refuges or relocation of the crossing point should be explored.
- Mirrors shall not be installed on public roads if viable Engineering solutions such as realignment or obstruction removal are possible in the short term.
- Due to image distortion and lateral inversion, road users may misinterpret speed or lane position. This risk must be weighed in the decision-making process.
- A formal road safety audit is recommended prior to installation on any public road to ensure the mirror is justified and its placement will not introduce new hazards.

7.21.4. Installation Guidelines

7.21.4.1 Mirror Selection

Convex mirrors used for roadside applications shall be specifically designed for outdoor traffic safety use and constructed from durable, impact-resistant, vandal-resistant, and weatherproof materials, suitable for long-term performance under varying environmental conditions. Only the following mirror face materials shall be permitted:

- Highly polished stainless steel: Offers excellent resistance to corrosion, scratching, and vandalism. Suitable for high-risk locations or exposed public areas where a long service life is critical.
- Polycarbonate (PC): UV-stabilized, lightweight, and impact-resistant, appropriate for general road safety use in low to moderate exposure conditions.

Acrylic (PMMA) or glass mirrors shall not be permitted due to their lower durability and impact resistance in public roadside environments.

Technical Parameters and Requirements:

- Mirror Face Thickness:
 - Stainless steel: Not less than 0.8 mm
 - Polycarbonate: Not less than 1.5 mm
- Standard Mirror Sizes: 600 mm, 800 mm, and 1000 mm in diameter, selected based on required viewing distance and road geometry.
- Viewing Angle: Mirrors shall provide a minimum horizontal viewing angle of 100° to 130°, depending on size and curvature.
- Backing Material: The rear housing shall be made of impact-resistant Acrylonitrile Butadiene Styrene (ABS) or polypropylene (PP), with UV-stabilized and weather-resistant properties to protect the mirror structure from deformation or environmental damage.
- Mounting Bracket: Mirrors shall be supplied with a galvanized steel universal bracket allowing 360° horizontal and vertical adjustment. The bracket shall be suitable for both pole and wall mounting and designed to resist wind-induced vibration.
- Additional Features:
 - Sun Visor or Hood: To reduce dust accumulation and glare from direct sunlight or vehicle headlights.
 - High-Visibility Border: Reflective or brightly colored outer ring (e.g., red-white or yellow-black) to improve detectability, especially for unfamiliar road users.

7.21.4.2. Installation Requirements

Convex mirrors shall be securely mounted on poles, walls, or suitable fixed structures to prevent tampering and ensure visibility. The installation location must offer the optimal angle of view for detecting oncoming vehicles from the obstructed direction. The mirror should be adjusted to

accommodate drivers of various vehicle types, ensuring that the likely conflict vehicle is visible near the center of the mirror from typical eye heights.

Mirrors with smaller diameters typically have tighter curvature, resulting in increased image distortion. For this reason, larger mirrors with flatter curvature shall be used to enhance clarity and provide a more realistic visual perception of distance and vehicle speed.

Where necessary, multiple mirrors may be installed to provide a complete field of view if a single unit is insufficient. Additionally, installers must assess potential headlight glare at night and sunlight reflections during dawn or dusk when determining mirror placement.

7.21.4.3. Signage

The use of appropriate warning signs is mandatory. A sign indicating “DISTORTED IMAGE” shall be mounted directly beneath the mirror to inform drivers about potential image misinterpretation. Where the mirror’s location is not clearly visible from the approach, an advance warning sign stating “CONVEX MIRROR AHEAD” should be installed in accordance with approved signage standards and the Engineer’s direction.

7.21.5. Measurement

The quantity to be measured for payment shall be the number of convex mirrors installed, complete in all respects and accepted by the Engineer. This shall include the mirror, pole (galvanized/painted), foundation, and all associated installation works.

Signage, such as “DISTORTED IMAGE” or “CONVEX MIRROR AHEAD”, shall be measured and paid for separately under the relevant items of Section 71: Traffic Signs of this Specification.

7.21.6. Payment

Payment shall be made at the contract unit rate per item and shall constitute full compensation for the supply of the convex mirror, supporting pole (galvanized/painted), mounting accessories, and all associated materials; execution of foundation works including excavation, concreting, backfilling, and compacting; and installation of the mirror including visor or hood, adjustable galvanized mounting bracket, fitting, fixing, alignment, high-visibility border; and for all labor, equipment, tools, and incidental works necessary to complete the installation in accordance with this Specification.

Pay items shall be:

Pay Items	Description	Unit

7.21.1	Supply and installation of a convex mirror of approved size with mounting accessories, and all associated materials, including supporting pole (galvanized/painted) and foundation works.	Number
(a)	600 mm	
(b)	800 mm	
(c)	1000 mm	

7.22. Anti-Glare Systems

7.22.1. General

Anti-glare screens are installed to reduce or block the glare of headlights from opposing traffic, improving night-time driving safety and visibility. This section covers the requirements for supply, installation, and performance of anti-glare systems, including the provisions for design, material properties, optical effectiveness, mechanical strength, structural fixation, durability, and performance testing of anti-glare screens to be used along medians, safety barriers, or crash barriers on highways and expressways. This specification does not apply to anti-glare systems not fixed to safety barriers, nor does it cover requirements related to the regulatory characteristics or visibility of traffic signs or special conditions associated with extreme climates.

The anti-glare system shall be constructed of vertically mounted occluding elements, fabricated from high-performance synthetic materials or equivalent, and mounted either directly on concrete barriers or on dedicated support structures. The design shall comply with the relevant provisions of EN 12676-1 and EN 12676-2, as well as the guidance outlined in the RHD Road Safety Engineering Manual 2024.

7.22.2. Material and Structural Requirements

2. Material Composition

- The occluding plates shall be manufactured from synthetic elements like low-pressure high molecular weight polyethylene (HMWPE) or an equivalent polymer, stabilized against ultraviolet degradation and color fading.
- Metallic parts shall be inherently resistant to corrosion (or coated with protective finishes), including mechanical wear, chemical agents, and a broad range of environmental conditions.
- Galvanized components must comply with section 7.1.2.5 of this Specification.

3. Geometric Properties

- Plate Height: 600 mm, 900 mm, or 1200 mm as per site and occlusion requirements.
- Plate Width: 220 mm or 267 mm or other industrial sizes conforming to design and fixation requirements.
- Thickness: Minimum 6 mm or as required by site-specific wind load calculations.
- Anti-glare screens shall have no sharp corners on which people can get hurt.

4. Surface Finish and Color

- Surface shall have a matte, non-reflective finish, free from glare-inducing reflections.
- Color: standard green or grey, UV-stable and visually neutral.

6. Mounting System

- Mounting brackets and posts shall be fabricated from hot-dip galvanized steel, conforming to section 7.1.2.5 of this Specification.
- All fasteners shall be stainless steel or similarly corrosion-protected.
- Post spacing and anchorage shall be determined based on wind loading, barrier type, and structural design.

7.22.3. Design and Fixation Requirement

The design of the anti-glare screen shall comprise vertically oriented occluding elements, which may be installed either directly on the barrier base or mounted on a supporting structure, as illustrated in the Engineering drawings.

Under normal conditions, no part of the installed anti-glare screen, including its components or fastening mechanisms, shall extend beyond the outer edge of the safety barrier. However, in the case of concrete barriers, it is permissible for the upper edge of synthetic occluding elements to extend up to 100 mm beyond the barrier face, provided this does not compromise safety or structural integrity.

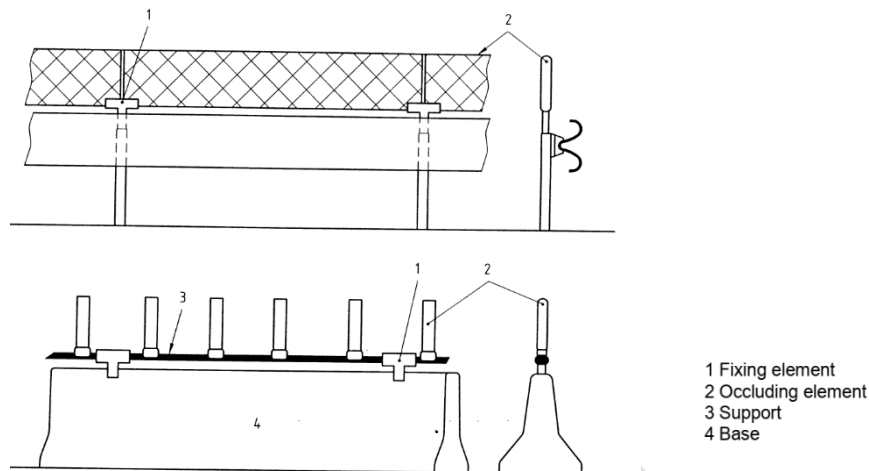


Figure 7.22-1: Examples of Anti-glare systems.

Anti-glare systems are categorized into two groups based on their lateral visibility:

- **Group 1 (High Visibility):**

Systems in this category maintain good lateral visibility by ensuring that the solid portion of the occluding elements occupies no more than 20% of a 1 m (length) × occluder height (vertical) rectangle, viewed in a vertical plane parallel to the road axis.

Recommended Use:

- Urban or peri-urban areas where lateral visibility for drivers, pedestrians, and roadside activities is important.
- Sections requiring enhanced situational awareness, such as intersections, roundabouts, or near pedestrian crossings.

- **Group 2 (Low Visibility):**

Systems that do not meet the 20% transparency criterion fall under Group 2. These provide more complete glare blocking but reduce lateral visibility.

Recommended Use:

- High-speed expressways or isolated segments with limited need for side visibility.
- Areas where maximum glare suppression is the primary objective and lateral visual access is less critical (e.g., tunnels, long straight medians, or controlled-access roads).

Two major types shall be considered based on glare/optical performance requirements.

- **Type A (Geometrical Blocking):**

- Must satisfy: $\tan \alpha_1 \geq L/D = 0.33$; where L = effective width of occluder, D = spacing of screening elements.
- No transmission factor (C_{ti}) test required if the above condition is met.

- Type B (Partial Blocking):
 - For systems where $\tan\alpha_i < L/D = 0.33$, C_{ti} shall be tested as per EN 12676-2 and interpreted in RHD Road Safety Engineering Manual 2024 and shall be compliant for thresholds of transmission factors at different incident angles.

Refer to RHD Road Safety Engineering Manual 2024 for definitions of incidence/limiting angle (α_i) and transmission factor (C_{ti}).

7.22.4. Construction and Application

Installation Guidelines

- Anti-glare screens shall be securely fixed to Jersey barriers, crash barriers, or dedicated support structures as specified in the design drawings.
- The system alignment shall conform to the approved geometric layout, ensuring a continuous and uniform installation.
- No part of the screen shall encroach into the carriageway that can pose a physical hazard to traffic.
- The installation shall facilitate easy removal and replacement of individual units for maintenance or repair.

Maintenance Provisions

- All hollow sections must be sealed at the top to prevent ingress of water, dirt, and nesting by birds.
- The system shall be modular, allowing for the independent replacement of any damaged section without disturbing adjacent parts.
- Routine maintenance should only be required in the event of impact or extreme environmental conditions.

Functional Application

Anti-glare systems are primarily required on National Highways, Expressways, and urban or peri-urban road sections, particularly in the following scenarios:

- Narrow median widths
- High volumes of night-time traffic
- Horizontal and vertical curves (sag or crest)
- Opposing carriageways at vertical offsets less than 2 m
- Proximity to parallel roadways with opposing flows

- Near tunnel approaches and exits
- Locations exposed to glare from ambient or external lighting sources
- Urban or peri-urban areas where lateral visibility for drivers, pedestrians, and roadside activities is important
- Sections requiring enhanced situational awareness, such as intersections, roundabouts, or areas near pedestrian crossings

Operational Parameters

- Operational temperature range: -40°C to +60°C.
- The installation height or minimum effective height of the anti-glare screen shall be determined according to the formula and procedures described in the relevant section of the RHD Road Safety Engineering Manual 2024. The following guidelines are generally followed:
 - An anti-glare screen height of at least **1.18** m above ground level is sufficient to protect drivers of light vehicles from glare originating from the outer lanes of an opposing carriageway (two lanes/ carriageway).
 - A screen height of at least **1.67** m is required to shield heavy vehicle drivers from glare from the outermost lane of the opposite carriageway (two lanes/ carriageway).
 - A height of over **2.24** m is needed to ensure complete glare shielding for heavy vehicle drivers against glare from vehicles in multiple outer lanes (more than two lanes/ carriageway).
 - These values are conservative and ensure compliance under most standard road conditions. Site-specific evaluations are advised for non-standard layouts where curvature, crossfalls, or unusual vehicle mix is present (see RHD Road Safety Manual 2024).
- Spacing of occluding elements shall be determined based on the optical performance required for Type A (Geometrical Blocking) or Type B (Partial Blocking) as described in detail in RHD Road Safety Engineering Manual 2024. However, the spacing of modular vertical types typically ranges from 0.5 m to 1.0 m, with the width of elements between 220 mm and 300 mm, depending on the visual shielding performance.
- A gap of up to 20 mm between the base and the bottom edge of the occluding elements is permissible.

Glare Shielding Angle

It is generally considered that an unscreened beam does not disturb oncoming drivers if it reaches them at a wide incident angle. In general, it is considered that the disturbance is negligible for $\alpha > 30^\circ$. However, the following conditions shall be met for

- The anti-glare system shall be capable of shielding headlight glare for incident angles of at least 8° under standard highway conditions.
- For horizontal and vertical curves, this angle should be increased from 8° to 15° to ensure full visual protection.
- Design of anti-glare facilities must ensure that sight distances and forward visibility are not compromised. If necessary, median widening or alternate treatments shall be considered.

Special Precautions

- Anti-glare elements shall not use reflective materials.
- The system may be attached to safety barriers without compromising their crashworthiness or energy-absorbing function.
- At intersections, median openings, and pedestrian crossings, a high-visibility anti-glare system shall be used or shall be terminated in advance to avoid obstructing driver visibility of pedestrians, signals, or cross traffic.

7.22.5. Testing Requirements

Durability of Synthetic Materials

The durability of synthetic components shall be confirmed by evaluating their impact resistance both before and after undergoing artificial ageing, following the procedures outlined in EN 12676-2. For unaged specimens, the variation in tensile impact strength between test temperatures of $(23 \pm 3) ^\circ\text{C}$ and $(-30 \pm 3) ^\circ\text{C}$ shall not exceed 15%. Following the ageing process, each tested sample must retain at least 80% of its original tensile impact strength.

Resistance to Wind

- The anti-glare system shall be wind tunnel tested at 40 m/s (144 km/h) as per EN 12676-2.
- Deformation limits:
 - Max 10% in transverse direction
 - Max 25% in longitudinal direction
- If available in multiple heights, only the tallest variant shall be tested.

7.22.6. Measurement

The quantity of anti-glare systems shall be measured according to their type and configuration. For modular vertical units, the measurement shall be made by counting the total number of units installed and accepted at the site, in accordance with the approved Engineering drawings and Specifications. This shall include the post, occluding element, base connection, and all fixation hardware. For

continuous screen systems, measurement shall be in linear meters, taken along the centerline of the installed length, and shall include all components such as panels, brackets, posts, and fasteners necessary for complete installation.

No separate measurement shall be made for excavation, alignment, finishing, or testing. All components and activities necessary for ensuring durability, safety, and compliance, including corrosion protection, UV resistance, impact testing, wind resistance testing, and lateral visibility conformity, shall be considered incidental to the item and included within the respective unit or linear meter rate.

7.22.7. Payment

Payment shall be made under the respective contract unit rates and shall constitute full compensation for the supply and installation of all materials, including occluding elements, mounting brackets, posts, fasteners, protective coatings, and structural supports; surface preparation and alignment; fabrication, shaping, and erection of anti-glare units; execution of required anchorage and fixation; and for all labor, equipment, tools, testing, transportation, and incidental works necessary to complete the item in accordance with this Specification.

Pay items shall be:

Pay Items	Description	Unit
7.22.1	Anti-Glare Screen (modular vertical units)	Number
7.22.2	Anti-Glare Screen (continuous screen systems)	Lin. meter

7.23. Sound Barrier

7.23.1. General

This work includes the design, supply, installation, and testing of sound barrier systems to reduce highway traffic noise levels in residential, institutional, recreational, or environmentally sensitive areas. These barriers shall be constructed in accordance with acoustic design principles and structural requirements, using high-quality and durable materials that meet international standards for noise insulation, absorption, and mechanical stability.

Sound barriers may consist of absorptive, reflective, or combined panels, installed along the roadside on suitable foundations with adequate anchoring systems. The design shall comply with the relevant provisions of EN 14388 (general requirements), EN 1793 series (acoustic performance), EN 1794 series (non-acoustic performance), EN 14389 (long-term performance requirements), as well as the guidance outlined in the RHD Road Safety Engineering Manual 2024.

7.23.2. Acoustic Performance Requirements

The noise barrier system shall be evaluated for acoustic performance under both laboratory and in-situ conditions. Performance indices for acoustic performances are described in the RHD Road Safety Engineering Manual 2024.

a. Sound Absorption Performance (EN 1793-1:2017)

The sound absorption characteristic, applicable to absorptive and combined panels, shall be tested under diffuse sound field conditions.

- Measured Index: DL_{α} (Single-number rating of sound absorption)
- Minimum Requirement:
 - $DL_{\alpha} \geq 6$ dB, corresponding to Class A2 or higher (See RHS Road Safety Manual 2024) as an intrinsic absorption rating

b. Airborne Sound Insulation Performance (Laboratory) (EN 1793-2:2018)

This evaluates the barrier's ability to block sound transmission under reverberant conditions (e.g., tunnels or narrow corridors).

- Measured Index: DL_R (Single-number rating of airborne sound insulation)
- Minimum Requirement:
 - $DL_R \geq 24$ dB for all panel types (absorptive, reflective, or combined)

c. Airborne Sound Insulation Performance (In Situ) (EN 1793-6:2018)

For verifying actual installed performance, the system shall be assessed using direct sound field conditions with mobile equipment.

- Measured Index: DL_{SI} (Sound Insulation Index, in situ)
- Minimum Requirement:
 - $DL_{SI} \geq 24$ dB, aligned with laboratory DL_R values
- This is mandatory for verifying performance post-installation, and for long-term compliance monitoring.

7.23.3. Non-Acoustic Performance Requirements

The noise barrier system shall be evaluated and certified for the following non-acoustic performance parameters, in accordance with the requirements of EN 1794-1:2024 and EN 1794-2:2024:

a. Mechanical and Structural Performance (EN 1794-1)

1. Resistance to Horizontal Loads: The barrier shall withstand horizontal loads arising from wind and traffic pressure. Testing shall follow Annex A of EN 1794-1. Results must confirm structural integrity under service and ultimate load conditions across the temperature range of -40°C to $+70^{\circ}\text{C}$. No permanent deformation, displacement, or loss of integrity under both service and ultimate loading conditions.
2. Resistance Under Self-Weight: Panels and structural elements must support their own dry and wet weight without deformation or detachment. Permanent deformation shall not exceed $LA/500$.
3. Impact Resistance from Stones: Panels shall withstand impact from projected debris, such as stones. Damage shall not affect mechanical or acoustic performance. Required test shall be conducted in accordance with EN 1794-1:2024, using a minimum impact energy of $30 \text{ Nm} \pm 1 \text{ Nm}$. Following the impact, the panels must exhibit no fractures, internal damage, or structural failure. Only superficial surface damage, such as shallow dents or minor surface cratering, is permissible.
4. Collision Safety (if combined with safety barrier): If the noise barrier system is integrated with a road restraint system, it shall comply with EN 1317-1 and EN 1317-2 performance classes, including containment class (e.g., N2, H1, H2) (see RHD Road Safety Engineering Manual 2024). The complete system must be crashworthy, redirective, and securely anchored.

b. Safety and Environmental Requirements (EN 1794-2)

1. Fire Resistance (Brushwood Fire): Panels shall be tested as per Annex A of EN 1794-2. A minimum classification of Class 2 is required. Panels shall be tested in accordance with EN 1794-2:2024, which assesses fire resistance performance under exposure to a standardized brushwood flame. The minimum required classification is Class 2 (see RHD Road Safety Engineering Manual 2024), which is defined as follows:
 - Surface damage shall be limited to a burned area $\leq 0.06 \text{ m}^2$,
 - Vertical flame spread shall not exceed 200 mm from the point of ignition,
 - No burn-through of the panel is allowed.

This classification ensures that the barrier can withstand roadside fires (such as from burning vegetation or vehicles) without compromising structural integrity or posing a hazard to traffic

2. Risk of Falling Debris: Noise barriers installed on bridges, flyovers, or elevated roadways shall be evaluated as per EN 1794-2:2024 for their ability to retain and restrain components under impact to prevent falling debris.

The system shall meet a minimum restraint classification of Class 3 (see RHD Road Safety Engineering Manual 2024), which corresponds to:

- Test impact energy of 6.0 kJ, simulating an object of 400 kg dropped from a height of 1.5 meters.
- The system must resist the impact without allowing any component (e.g., panels, fasteners, or frames) to detach and fall below the structure.

The fastening and anchorage system must be designed to maintain mechanical continuity and resist dynamic loads, ensuring the safety of road users and infrastructure beneath elevated installations.

3. Light Reflection: Reflective surfaces of noise barriers shall be evaluated in accordance with EN 1794-2:2024 to ensure that excessive glare and light reflection do not pose a hazard to drivers or pedestrians.
 - Gloss level measurements shall comply with EN ISO 2813, using standard angles of incidence: 20°, 60°, and 85°
 - Surfaces must exhibit controlled reflectivity, and visual assessment shall confirm that glare is non-disruptive under daytime or headlight illumination.
 - No minimum gloss class is prescribed, but the reflectance profile must be documented and submitted for approval, especially for panels located near curves, signal zones, or urban settings.
4. Transparency (for clear panels): Transparent elements such as polycarbonate or acrylic sheets shall be tested in accordance with EN 1794-2:2024 to ensure safe visibility and aesthetic clarity.
 - The following criteria shall be met:
 - Light Transmission Index (LT) $\geq 88\%$, confirming high daylight permeability.
 - Static and dynamic transparency shall be assessed, including:
 - Obscuration angles (i.e., how much visibility is blocked by the framing or reflection),
 - Distortion when viewed in motion (e.g., by drivers or cyclists),
 - Resistance to yellowing, haze, and UV degradation over time.

Panels that do not meet these requirements shall not be used in locations where visual continuity, driver perception, or pedestrian safety are critical (e.g., near intersections, pedestrian bridges, or scenic corridors).

5. Environmental Protection: All component materials must be declared chemically (not just by trade name), including:
 - Potential leachates under environmental exposure.
 - Fire emissions (if toxic).
 - % of recycled content (if applicable).Reference: Annex C, EN 1794-2.
6. Maintenance and Emergency Access: The barrier shall provide access doors or removable panels, facilitating:
 - Emergency exits.
 - Maintenance access.
 - Escape paths from traffic incidents.

7.23.4. Materials

The noise barrier system shall be composed of durable, weather-resistant, and structurally stable materials, designed to ensure long-term performance under varying environmental and mechanical loads. The material components shall include:

1. Foundation Materials: Foundations shall be constructed using cast-in-situ reinforced concrete, formed as pedestals or continuous strip footings in accordance with the approved design drawings.
 - Concrete Grade: Not less than C2.
2. Support Post Materials: Support structures shall be fabricated from rectangular hollow sections (RHS) or I-beams made of hot-dip galvanized steel.
 - Galvanization shall conform to section 7.1.2.5 of this Specification.
 - Posts shall be structurally designed to resist wind loads up to 144 km/h.
3. Noise Barrier Panel Materials
 - Absorptive Panels: Constructed with an outer steel casing featuring a perforated face, enclosing a mineral wool core with a density between 75–175 kg/m³. The core shall be wrapped in a water-resistant film to prevent moisture intrusion.
 - Reflective Panels: Manufactured from transparent acrylic glass or polycarbonate sheets, providing a minimum tensile strength of 60 MPa.
 - Combined Panels: Incorporate a lower absorptive section and an upper transparent section to achieve both acoustic attenuation and visual openness.
4. Sealing and Fastening Materials

- Seals: All joints shall be fitted with EPDM¹⁰ (Ethylene Propylene Diene Monomer) rubber gaskets or equivalent weatherproof, acoustic sealing materials to prevent air leakage and acoustic bridging.
- Fasteners: All bolts, nuts, washers, and anchors shall be made of stainless steel, conforming to ASTM A240 and equipped with anti-vibration locking mechanisms to ensure mechanical stability under cyclic loads.

7.23.5. Constructions

- All barriers shall be constructed and erected on-site using equipment and workmanship approved by the Engineer.
- Panel erection shall ensure vertical and horizontal alignment, with consistent spacing and anchoring as per the manufacturer's guidelines.
- Damage to panels during transport or installation shall lead to replacement at no extra cost.
- All surfaces must be finished to ensure corrosion protection and durability under local climatic conditions.

7.23.6. Test requirements/Manufacturer Reporting Requirements

The manufacturer/contractor shall submit a comprehensive technical dossier confirming compliance with the applicable standards for sound barrier systems. The following table summarizes the required characteristics to be reported, indicating whether a declared value, class, or compliance statement is mandatory.

Table 7.23-1: Reporting requirements for sound barrier systems

Characteristic	Relevant Standard	Requirement for Manufacturer Reporting
Sound absorption	EN 1793-1	Report DL_{α} value or class (e.g., A2, A3) if described as absorptive (E_i)
Airborne sound insulation (Lab)	EN 1793-2	Mandatory: Report D_{LR} value or declare performance
Airborne sound insulation (In Situ)	EN 1793-6	Mandatory: Report DL_{SI} value for installed systems
Wind and static loading	EN 1794-1	Mandatory: Report tested compliance
Self-weight resistance	EN 1794-1	Mandatory: Report permanent deformation test results

¹⁰ EPDM (Ethylene Propylene Diene Monomer) is selected for its exceptional resistance to weathering, ozone, ultraviolet (UV) radiation, and temperature extremes, making it particularly suitable for long-term outdoor applications. The sealing system provides effective acoustic sealing by preventing air leakage and minimizing sound transmission through panel joints. It maintains elasticity and compression recovery over a wide operational temperature range, typically from -40°C to $+120^{\circ}\text{C}$. In addition, EPDM is chemically inert and resistant to water, alkalis, dilute acids, and automotive pollutants such as oils and greases. The material demonstrates long-term durability, with a minimum expected service life of 20 years under standard highway environmental conditions.

Impact resistance from stones	EN 1794-1	Mandatory: Minimum 30 Nm impact energy, no internal damage
Collision safety (vehicle occupant)	EN 1794-1	Optional: Only if relevant for the project
Collision safety (combined with barrier)	EN 1794-1 + EN 1317	Required if part of a combined safety-noise barrier (E ₂)
Fire resistance (brushwood fire)	EN 1794-2	Mandatory: Report minimum Class 2
Danger of falling debris	EN 1794-2	Mandatory: Report restraint Class 3 or higher if installed on elevated structures
Environmental protection	EN 1794-2	Mandatory: Declare chemical composition, leachates, recycled content
Means of escape (access panels)	EN 1794-2	Required if access panels or doors are included
Light reflection	EN 1794-2	Mandatory: Report gloss values (20°, 60°, 85°) per EN ISO 2813
Transparency (for clear panels)	EN 1794-2 + EN 410	Required if transparent panels are used: Report LT ≥ 88%, obscuration, distortion
Diffraction index improvement	CEN/TS 1793-4	Optional: Report only if intended to enhance diffraction performance

Note: E₁: Applicable only if the device is sound absorptive; E₂: Applicable only if the barrier is classified as a combined safety and noise barrier.

All test results shall be from accredited laboratories. The manufacturer/contractor must submit complete test reports, certificates, and supporting documents demonstrating compliance with each applicable characteristic.

7.23.7. Measurement

The measurement of the sound barrier system shall be made in linear meters, taken along the centerline of the completed and accepted installation in accordance with the approved Engineering drawings and this Specification. The measured length shall include the full extent of the barrier system, regardless of changes in height or terrain, and shall encompass all integral components such as panels (absorptive, reflective, or combined), support posts, foundations, gaskets, and fasteners. No separate measurement shall be made for excavation, backfilling, formwork, surface treatment, alignment, testing, or any other incidental works. All elements necessary to achieve compliance with the specified acoustic and non-acoustic performance requirements shall be considered incidental and included within the measured length.

7.23.8. Payment

Payment for the sound barrier system shall be made at the contract unit rate for the installed, tested, and accepted barrier, measured as specified above. The unit rate shall be deemed to include full

compensation for the design, supply, transportation, installation, and alignment of all components, including panels, support posts, concrete foundations, acoustic sealing gaskets, stainless steel fasteners, and anchoring devices. It shall also cover all labor, equipment, surface treatments, testing for acoustic and non-acoustic performances, and all incidental works required to complete the item in full compliance with the Specification and to the satisfaction of the Engineer.

Pay item shall be:

Pay Item	Description	Unit
7.23.1	Sound Barrier System	Lin. meter

7.24. Street Lighting

7.24.1. General

Street lighting systems shall be installed to enhance road user safety, nighttime visibility, and the efficient movement of vehicular and pedestrian traffic under low-light or reduced visibility conditions. This section covers the requirements for the planning, supply, installation, and performance of street lighting systems, including design considerations, photometric performance, energy efficiency, structural support, safety, and electrical compliance of luminaires and associated infrastructure to be deployed along national highways, urban corridors, intersections, and other high-priority locations.

The system design shall adhere to the provisions of the EN 13201 series, including EN 13201-2 for performance requirements, EN 13201-3 for performance calculation, EN 13201-4 for measurement methods, and EN 13201-5 for energy efficiency indicators. Guidance from CEN/TR 13201-1 (lighting class selection), CIE 115, BS 7671: Requirements for Electrical Installations, and RHD Road Safety Engineering Manual 2024 shall also be followed to ensure appropriate luminance levels, uniformity, glare control, and electrical safety. This specification does not apply to temporary or decorative lighting systems, sign illumination, or aesthetic purposes, which are governed by separate standards.

7.24.2. Determination of Lighting Classes for Motorized Traffic

The relevant requirements for lighting class selection and photometric performance criteria for motorized, pedestrian, and conflict areas are provided in the RHD Road Safety Engineering Manual 2024. These specifications align with the EN 13201 series and serve as the standard reference for all road lighting designs under RHD.

7.24.3. Technical Requirements for the Lighting System

Luminaire Type and Optical Characteristics

Street lighting systems shall be equipped with LED luminaires incorporating integrated optical systems that comply with the performance requirements of EN 13201-1 and EN 13201-2 for lighting classes M, C, and P, as applicable to the road type and user environment.

Luminaires shall be selected based on calculated compliance with the designated lighting class, considering pole height, spacing, and road geometry.

The system shall demonstrate optimized luminous efficacy, supporting energy-efficient operation in line with EN 13201-5. A reference value of 167 lm/W is considered appropriate for high-performance LED luminaires used in solar-integrated systems.

The Correlated Color Temperature (CCT) shall typically range from 3000 K to 5000 K, selected according to site context. Warmer CCTs (~3000 K) are preferred in residential or pedestrian areas for comfort and glare control, while cooler CCTs (up to 5000 K) enhance visibility on expressways and high-speed corridors.

The Color Rendering Index (CRI or Ra) shall be ≥ 80 , ensuring adequate object recognition and visual clarity under night-time conditions, particularly in mixed traffic or high pedestrian-use areas.

Lighting Design Compatibility

- Lighting performance shall be modeled using professional design software (e.g., DIALux, Relux), and validated by certified photometric files (.ldt or .ies format).
- Optics shall be designed for uniform spacing, ensuring compliance with the specified lighting requirements on motorways, conflict areas, and for non-motorized road users (pedestrians and cyclists).
- All lighting designs must be supported by documented calculations and submitted for approval prior to procurement.

Mechanical and Structural Features

- As a general guideline, mounting heights shall be:
 - Urban Traffic Routes, Main Distributor Roads: 10-meter.
 - Industrial Estate, Local Distributor and Access Roads: 8–10 meters.
 - Residential Roads, Access Roads, and Footpaths: 6-meter.
- All lighting poles shall be powder-coated with a UV- and corrosion-resistant finish/ Galvanized as per 7.1.2.5 of this Specification. The color shall conform to RAL 9007 (grey aluminum) or

as directed by the Engineer, ensuring aesthetic consistency and surface protection throughout the product's lifespan.

- The luminaire shall comply with an impact resistance rating of at least IK03 (IR3) as per IEC 62262 or EN 60598-1, suitable for general outdoor installation. Higher IK ratings (e.g., IK08 or IK10) may be specified in locations vulnerable to vandalism or mechanical impact.
- All components shall be modular and accessible for maintenance.

Table 7.24-5: Impact resistance rating IR3 (IEC 62262 / EN 60598-1).

IK Code	Impact Energy	Typical Protection Level
IK03	0.35 J	Light protection (e.g., for poles, signs)
IK06	1.0 J	Moderate protection (standard urban use)
IK08	5.0 J	High protection (public zones, vandal-prone)
IK10	20.0 J	Very high protection (tunnels, bridges)

Environmental and Safety Compliance

- The luminaire and support structure shall comply with:
 - Protection Class III (Extra low voltage). Defined in IEC 61140, Protection Class III luminaires are powered by SELV (Safety Extra Low Voltage) systems, usually <50 V AC or <120 V DC. They have no direct connection to mains voltage and rely on safe voltages that pose no risk of electric shock, even if touched.
 - EMC (Electromagnetic Compatibility) as per EN 50278 to ensure that the streetlight does not emit harmful electromagnetic interference (EMI) and is not affected by EMI from nearby sources (e.g., mobile towers, other electronics).
 - The luminaire enclosure shall provide IP66 protection in accordance with IEC 60529, ensuring complete resistance to dust ingress and protection against powerful water jets from any direction.
- Lighting systems shall not emit UV or IR radiation and shall minimize light pollution and ecological disruption.
- Systems must comply with relevant national acts (e.g., Environmental Protection Act, Hazardous Waste Regulations) where applicable.

Smart Control and Operation

- Lighting systems shall include microprocessor-controlled modules for autonomous operation, battery optimization, and dimming.
- Functions shall include:
 - Automatic ON/OFF switching at dusk and dawn,
 - Brightness adjustment based on battery level or time profile,
 - Synchronized operation across poles, ensuring visual continuity and safety.

- Optional integration with remote-control protocols may be specified for intelligent transport corridors or critical infrastructure zones.

7.24.4. Power Requirements for Street Lighting Systems

All street lighting systems shall be designed to ensure reliable, safe, and energy-efficient operation. Power supply configurations shall comply with applicable national codes and international electrical standards, including EN 13201-5, IEC 60598-1, and BS 7671 (Requirements for Electrical Installations).

- Luminaires shall operate on:
 - 230 V AC, 50 Hz for grid-connected installations, or
 - 12/24 V DC for systems with low-voltage operation (e.g., battery or hybrid supply).
- Power factor shall be ≥ 0.90 to minimize reactive power consumption.
- Total Harmonic Distortion (THD) of the luminaire driver shall not exceed 10%.
- Systems shall be equipped with:
 - Overvoltage and surge protection devices compliant with IEC 61643,
 - Proper earthing and grounding per national code for all metallic components,
 - Automatic circuit breakers or MCBs for each luminaire circuit.
- For energy performance evaluation, designers shall calculate and report the Power Density Indicator (W/m^2) and Energy Efficiency Indicator (kWh/km/year) as defined in EN 13201-5.
- For locations where continuity of lighting is critical (e.g., tunnels, toll plazas, interchanges, pedestrian bridges), the system shall include a backup power supply (e.g., battery bank or UPS) capable of maintaining full or partial lighting operation for a minimum of 6 hours in the event of a power outage.
- Backup autonomy duration shall be determined based on site-specific risk assessments, but shall not be less than the time required to safely evacuate, divert, or resume traffic control functions.
- The backup system shall automatically engage during main power failure and include low-voltage cut-off, overcurrent protection, and status indicators.
- Where required, battery enclosures shall provide at least 2 full lighting cycles (2 nights) of reserve in hybrid solar-grid systems.

7.24.5. Solar Street Lighting Systems

Solar-powered Street lighting systems shall provide autonomous lighting performance, designed for high-efficiency, low-maintenance, and all-weather operation. The design shall comply with IEC 62124, IEC 61730, IEC 61215, and relevant provisions of EN 13201-5 for energy performance.

a. System Configuration: Each solar lighting unit shall include:

- Photovoltaic (PV) panel (mono or polycrystalline), mounted at optimum tilt and orientation,
- LED luminaire with integrated optics and controller,
- Battery bank (LiFePO₄ or advanced GEL/VRLA) with sufficient autonomy,
- Charge controller with MPPT (Maximum Power Point Tracking) function.

b. Photovoltaic Panel: The system shall include a minimum of one 380 W solar panel (monocrystalline or polycrystalline), capable of meeting the total daily energy demand with sufficient margin. The panel shall comply with IEC 61215 and have a minimum conversion efficiency of 18%.

c. Battery Bank: The energy storage system shall consist of either:

- A 200 Ah AGM lead-acid battery (deep cycle), or A first-class Li-Ion battery (e.g., LG, Sony, Panasonic) with an equivalent lifetime of at least 4000-night cycles.
- The system shall be capable of operating for at least 21 consecutive nights (or 300 hours) without receiving any solar charge, ensuring reliable lighting performance during extended periods of cloudy or rainy weather.
- Battery enclosures shall be weatherproof (minimum IP65) and securely mounted.

d. Controller and Smart Features:

- MPPT charge controller with overcharge, over-discharge, and short-circuit protection.
- Automatic dusk-to-dawn switching.
- Programmable dimming profile (e.g., full brightness at peak hours, dimmed after midnight).
- Optional: Integration with remote monitoring systems (LoRa, GSM, Bluetooth) for status reporting and fault diagnostics.
- The controller shall have a minimum energy conversion efficiency of 97% and must offer full protection against overcharge, over-discharge, reverse polarity, and thermal stress. Custom-designed controllers by certified manufacturers such as ILST are acceptable.

e. Mounting and Housing:

- All components must be integrated or securely mounted to prevent theft or vandalism.
- Mounting hardware shall be corrosion-resistant and withstand wind speeds up to 144 km/h.
- Enclosures must meet IP65 (battery) and IP66 (luminaire) ratings.

7.24.6. Constructions

All public lighting systems installed and maintained should fully comply with BS 7671: Regulations for Electrical Installations 1992 and other related Legislation and Regulations (Highways Act 2021, Electrical Department guidelines, etc).

Installation will be done as per the manufacturer's standard guidelines or as per the instructions of the Engineer in charge.

7.24.7. Performance

The supplier shall provide a comprehensive written warranty covering all components of the street lighting system, including the luminaire, fixture finish, control electronics, power drivers, and energy storage elements. A minimum five-year on-site replacement warranty shall be offered, which shall include all associated costs of transportation, removal of defective products, and installation of replacements. The warranty shall cover material defects, workmanship, and finish deterioration. The fixture finish shall be warranted against failures such as cracking, peeling, blistering, chalking, or excessive fading due to environmental exposure. Luminaires that exhibit inadequate lumen maintenance or fail to meet the specified lighting class performance under EN 13201-2 by the end of the warranty period shall be replaced under this guarantee.

The LED source assemblies shall carry a five-year replacement warranty for non-starting units or premature failure. Drivers and integrated smart control units shall also be warranted for a period of five years. For solar-powered units, the battery system shall carry a minimum three-year manufacturer's warranty and must have a demonstrated service life of at least 4000-night cycles. Failures resulting from poor maintenance practices or excessive shading (greater than 50% shade factor) shall not be covered under the warranty. The photovoltaic panels shall be covered by a 10-year product warranty and a 25-year performance warranty, guaranteeing that power output will not decline by more than 0.8% per year, with not less than 80% of the rated output retained by the end of 25 years. Warranty certificates shall be formally issued to the Site Owner and submitted before final payment is authorized. The warranty period shall begin on the date of possession or system commissioning, whichever occurs first. The supplier shall also remain responsible for post-warranty support and repair services, as may be negotiated under separate terms.

7.24.8. Measurement

The quantity of street lighting systems shall be measured in units of complete lighting assemblies, separately categorized based on their power configuration: (a) solar-powered, and (b) hybrid (solar + grid) systems. Each unit shall include the luminaire, pole, mounting structure, power supply system (battery and/or grid connection), foundation, control components, distribution system, and all associated wiring and protections as specified in the contract. The measurement shall be based on the number of fully installed, tested, and commissioned units in accordance with the approved design and verified by the Engineer.

7.24.9. Payment

Payment shall constitute full compensation for the design, supply, transportation, erection, installation, wiring, surface protection (e.g., powder coating/galvanization), optical performance, testing, commissioning, and performance verification of all components. It shall also include integrated control modules, battery systems (for solar and hybrid configurations), photovoltaic panels, earthing arrangements, and all necessary civil works, including pole foundation and housing enclosures. The cost shall also cover the provision of warranty documentation, as well as any required training, tools, or manuals. No separate payment shall be made for trial operation, temporary works, or compliance tests.

Pay items shall be:

Pay Items	Description	Unit
7.24.1	Hybrid (solar + grid connection) Street Lighting	Number
7.24.2	Solar-powered Street Lighting	Number

7.25. Distance Marker (KM Post)

7.25.1. General

This work includes the supply, fabrication, transportation, and installation of precast reinforced concrete kilometer posts (distance markers) at designated chainages along the road alignment. The posts shall be installed as per the typical details shown on the Engineering drawings and at locations approved by the Engineer. The kilometer posts are intended to aid in road user navigation, maintenance management, and emergency response referencing.

7.25.2. Materials

The kilometer posts shall be precast using Grade C25/20 concrete in accordance with Section 6.10.2.1.3 of this Specification. All reinforcement shall be deformed steel bars conforming to the requirements of Section 6.8: Reinforcement for Concrete. Paint used for numbering, directional information, or color bands shall be weather-resistant, quick-drying enamel paint, approved by the Engineer. Lettering and numbering shall be applied using stencils of uniform font and size, ensuring visibility and durability under field conditions.

7.25.3. Construction Requirements

Kilometer posts shall be fabricated in accordance with the dimensions, cross-sections, and reinforcement details shown in the approved Engineering drawings. Each post shall be set vertically with proper alignment and partially embedded in a cement-sand mortar or concrete base to ensure

stability. Care shall be taken during transport and handling to avoid chipping, cracking, or surface damage. Any damaged post shall be rejected and replaced at no additional cost.

7.25.4. Measurement

Measurement shall be made in the number of units of concrete kilometer posts installed, completed, and accepted at the site in accordance with the Engineering drawings and Specifications. No separate measurement shall be made for foundation bedding, excavation, backfilling, painting, or lettering, which shall be considered incidental to the item.

7.25.5. Payment

Payment shall be made at the Contract unit rate per completed kilometer post. The rate shall be deemed to include full compensation for the supply of materials, casting, curing, surface finishing, painting, lettering, transportation, excavation, placement, alignment, and stabilization of the post, including all labor, equipment, tools, and incidentals necessary to complete the work in accordance with this Specification.

Pay item shall be:

Pay Item	Description	Unit
7.25.1	Kilometer Posts or Distance Markers	Number

7.26. Traffic Impact Attenuators/Crash Cushions

7.26.1. General

An impact attenuator, also known as a crash cushion, is a safety device designed to minimize the damage caused by vehicle collisions. These systems function by absorbing and dissipating the kinetic energy of an impacting vehicle, thereby reducing the severity of crashes and protecting both motorists and infrastructure.

Impact attenuators serve two primary purposes:

- **Energy Absorption:** They decelerate errant vehicles in a controlled manner, minimizing the risk of serious injuries.
- **Vehicle Redirection (for some types):** Certain designs help guide the vehicle away from hazards or work zones, reducing secondary collisions.

These devices are strategically installed in high-risk locations, such as gore areas, median barriers, bridge piers, and toll plazas, where direct vehicle impact could lead to severe consequences. Temporary versions are also commonly used in road construction zones to protect workers and equipment.

Crash cushion systems vary in design and composition, with some utilizing sand-filled barrels, water-filled modules, or metal-panel structures equipped with triggering mechanisms. The selection of an appropriate system depends on factors such as roadway speed, traffic volume, and the nature of the hazard being shielded.

All impact attenuators used in roadway applications should comply with relevant safety standards, such as those outlined in the American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH) or the National Cooperative Highway Research Program (NCHRP) Report 350, ensuring their effectiveness in real-world crash scenarios. The following specifications for different crash cushion systems are adapted from *the Highway Design Manual - Attenuation Systems (2002) of the New York State Department of Transportation (NYSDOT)*.

Design Considerations

- The total length and width of crash cushion arrays must be based on the design speed of approaching vehicles.
- Attenuators shall be installed on a stable foundation, such as reinforced concrete or asphalt, with a maximum allowable slope of 5% in any direction.
- Placement shall consider vehicle trajectory, ensuring the axis of symmetry aligns with the most likely direction of impact.
- Approach angles should not exceed 10° from the edge of the traveled way to avoid redirecting vehicles unpredictably.
- Curbs must be removed near attenuators to prevent vehicles from launching over the system upon impact

Types of Impact Attenuators

7.26.2. Gating Impact Attenuators

Inertial Sand Barrel Attenuators

Inertial sand barrel impact attenuators consist of a series of free-standing plastic barrels arranged in a sequence of increasing mass to absorb and dissipate impact energy. The gradual deceleration effect is achieved by placing lighter barrels at the front, which slow down smaller vehicles, and heavier barrels at the rear, which stop larger vehicles safely. These systems are commonly used in locations such as

gore areas, highway exits, and bridge abutments, where vehicles may unintentionally leave the roadway.

Design and Configuration

- **Weight Progression:** The standard module weights are 90 kg, 180 kg, 315 kg, 640 kg, and 950 kg, as recommended by AASHTO. The lighter barrels are positioned near the impact side, gradually increasing in weight towards the protected structure to ensure controlled deceleration.
- **Material:** The barrels are constructed from high-density polyethylene (HDPE), ensuring impact resistance and UV stabilization for durability in various weather conditions. Each barrel is filled with unbagged sand, which allows efficient energy absorption upon impact.
- **Typical arrangement for 100 km/h Impact Speed:**
 - Total layout dimensions: 10 meters in length, 2.5 meters in width.
 - Barrel distribution: 14 barrels in 9 rows, configured as follows:
 - Rows 1–4: One barrel per row.
 - Rows 5–9: Two barrels per row.
- **Placement Considerations:**
 - The axis of symmetry of the array must be directed along the most likely vehicle trajectory.
 - In gore areas, the system should be positioned towards the intersection of pavement edges to prevent unintended vehicle entry.
 - For roadside hazards, the angle between the array axis and the edge of the traveled way should not exceed 10°.
 - Obstacles in narrow medians should be shielded at both ends, with the modules flush with the downstream edge to prevent wrong-way impacts.
 - The barrels must be installed on a concrete or asphalt surface with a maximum slope of 5% in any direction to ensure stability.

Installation and Maintenance

- **Marking and Identification:** Each barrel's location and weight should be spray-painted on the ground before installation, ensuring easy reconstruction after impact.
- **Inspection and Compliance:** The contractor must provide manufacturer installation instructions, and the final setup must be inspected to verify correct positioning and filling according to standard specifications.

- Suitability: Sand barrels are one-hit systems, meaning they must be completely replaced after an impact. Therefore, they are best suited for low-impact-frequency locations, where repeated collisions are not expected



Figure 7.30-1: Inertial sand barrel attenuators.

Water-Filled Attenuators

Water-filled crash cushions serve as temporary or portable impact attenuators for work zones and construction areas.

These attenuators are water-filled modules connected by a shock-absorbing framework, often unanchored, making them easy to deploy and relocate. Impact-resistant plastic tanks are designed to contain water securely. Magnesium chloride additive may be used in cold regions to prevent freezing.

Used in temporary construction zones or locations requiring flexible barrier positioning. Water-filled attenuators require frequent maintenance to prevent evaporation or leaks. Not suitable for high-speed applications exceeding 100 km/h.



Figure 7.30-2: Water-filled attenuators.

7.26.3. Redirective Non-Gating Impact Attenuators (Proprietary Systems)

Telescoping Crash Cushion:

General: The Telescoping Crash Cushion is a redirective, non-gating impact attenuator designed to absorb the kinetic energy of a colliding vehicle and reduce crash severity. The system consists of crushable energy-absorbing cartridges and overlapping W-beam fender panels, which work together to bring the vehicle to a controlled stop. Upon impact, the system telescopes rearward, progressively dissipating energy and preventing abrupt deceleration. Unlike sand barrel attenuators, which require complete replacement after a crash, this system allows for modular repairs, making it a cost-effective solution for permanent high-speed roadway installations. It is particularly suitable for areas with frequent, high-speed collisions, such as highway exits, median barriers, and bridge piers.

Design and Construction: The system is composed of multiple energy-absorbing components strategically designed to handle impacts from both light and heavy vehicles. Its reinforced polyurethane foam cartridges are staged to crush upon impact, dissipating energy in a controlled manner. The Quad-Beam™ galvanized steel fender panels are arranged in overlapping layers, ensuring effective impact resistance while telescoping rearward during a collision. The system's diaphragms act as intermediate supports, guiding the energy dissipation process and maintaining structural integrity. Depending on the site requirements, the backup structure can be installed as a Tension Strut Backup or a Concrete Backup. To ensure stability, the system is secured with a polyester anchoring system, which meets FHWA impact resistance standards.

Installation and Site Preparation: Proper foundation preparation is crucial for the effectiveness of the Telescoping Crash Cushion. The system must be mounted on a reinforced concrete base, with a minimum thickness of 200 mm and 28 MPa compressive strength, ensuring durability against repeated impacts. The installation site must have a maximum allowable cross-slope of 8%, with minimal twisting over the length of the system to maintain alignment. During assembly, lower-positioned front cartridges optimize energy absorption, while fender panels are secured with rail bolts to allow smooth telescoping upon impact. To prevent obstruction, the backup structure must be installed at least 760 mm forward of any rigid objects, allowing for full rearward collapse during a crash. These installation and site requirements ensure optimal system performance, providing long-term crash protection with minimal maintenance needs.

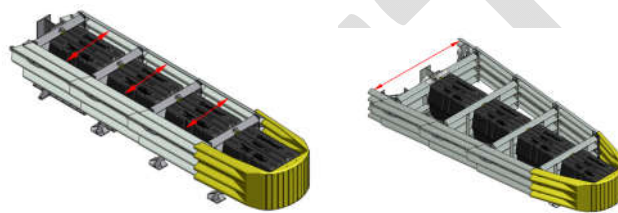


Figure 7.30-3: Parallel and wide system of Telescoping Crash Cushion.

Self-restoring crash cushion: This system is a redirective, non-gating crash cushion designed for high-speed highways and locations with frequent impacts. It consists of a series of high-density polyethylene (HDPE) barrels that are connected by side cables and mounted on a reinforced concrete base. Upon impact, the barrels compress and dissipate kinetic energy, bringing the vehicle to a controlled stop. This system is engineered for multiple impacts, meaning that after minor crashes, it can self-restore without needing full replacement. The steel cable support structure provides additional stability, ensuring that the system remains intact during side-angle collisions.

Compared to sand barrel attenuators, the System offers superior redirection capabilities, preventing errant vehicles from penetrating or passing through. It is especially suitable for locations where redirection is crucial, such as high-speed roadways, bridge piers, and gore areas. However, while the system is more cost-effective in the long run due to its reusability, post-impact maintenance is still required, as some components may need replacement after significant crashes. Despite a higher initial investment compared to sand barrels, the long-term savings in maintenance and replacement costs make the system a preferred choice for permanent safety installations.



Figure 7.26-4: Examples of self-restoring crash cushion systems.

Source: New York State Department of Transportation (NYSDOT). (2002). *Highway Design Manual – Attenuation Systems*. Retrieved from <https://www.dot.ny.gov/hdm/hdm-repository>.

7.26.4. Measurement

The quantity to be measured for payment shall be after completed work including preparation and construction of necessary foundation work, maintenance of the system for the operation period as directed by the Engineer and the testing and compliance of the systems as per the American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH) or the National Cooperative Highway Research Program (NCHRP) Report 350.

7.26.5. Payment

The traffic impact attenuator system shall be measured and paid for design and installation of each system as a complete job at each location.

Pay items shall be:

Pay Items	Description	Unit
7.26.1	Inertial sand barrel crash cushion	Number
7.26.2	Water-filled crash cushion	Number
7.26.3	Telescoping crash cushion	Number
7.26.4	Self-restoring crash cushion	Number

7.27. Rectangular Rapid Flashing Beacons (RRFB) for Pedestrian Safety

7.27.1. General

This work shall consist of the supply, installation, testing, and commissioning of Rectangular Rapid Flashing Beacons (RRFB) at designated pedestrian crossings to enhance pedestrian safety by increasing the conspicuity of crosswalks. RRFBs are user-activated warning systems consisting of dual, high-intensity LED beacons that flash in an alternating pattern to alert motorists of the presence of pedestrians. The RRFBs shall comply with the requirements of the *Manual on Uniform Traffic Control Devices (MUTCD), 11th Edition*, and be suitable for deployment at uncontrolled pedestrian crossings, mid-block crossings, and roundabouts.

7.27.2. Materials and Components

The RRFB system shall comprise the following components:

Component	Specification
Beacon Lights	Dual rectangular amber LED lamps (minimum 76 mm x 178 mm), UV-resistant, meeting Class 1 luminous intensity per SAE J595 ¹¹
Side Indicator	Amber LED side indicators (25 mm x 75 mm) to indicate activation status to pedestrians
Material (Beacons)	Fabricated from black powder-coated, vandal-resistant aluminum
Enclosure	Vandal-resistant aluminum housing with black powder coating; lockable access with corrosion-resistant quarter-turn mechanism; compliant with NEMA 4X and IP66 standards, ensuring complete protection against dust, corrosion, and high-pressure water ingress suitable for outdoor, all-weather operation (IP67 recommended in flood-prone areas).
Solar Power System	High-efficiency monocrystalline solar panels, minimum 50W capacity; 360° adjustable mounting; certified to CE (Conformité Européenne – EU), and IEC (International Electrotechnical Commission) standards
Battery System	Sealed, maintenance-free AGM-type batteries; recyclable; capacity of 20Ah (standard) or 40Ah (extended); operational temperature range: -40°C to +65°C
Control Box/System	Integrated module inside the enclosure housing the intelligent controller, surge protection, battery interface, and communications unit; supports remote configuration, power management, and diagnostics
Connectivity Features	Supports real-time remote monitoring and diagnostics via a secure web-based platform. Enables wireless communication between field units (beacons, sensors, controllers) using Bluetooth Low Energy, with synchronization across up to 7 devices and a maximum communication range of 350 meters.

¹¹ SAE J595 is a standard developed by the Society of Automotive Engineers (SAE International) that specifies performance requirements for flashing optical warning devices (e.g., beacons, strobe lights) used on authorized vehicles and road safety systems.

Network System	Supports wide-area communication over 4G LTE with Category Cat-M1/NB2 (NTN) modules. Compatible with frequency bands: B1, B2, B3, B4, B5, B8, B12, B13, B18, B19, B20, B23, B25, B26, B28, B66, B85, B255, B256. Accepts multi-operator SIM cards. Operates on TCP/IP protocol for secure, real-time data exchange with backend systems.
Activation	Activation via weatherproof push button (mechanical or piezo-type) and/or passive pedestrian detection; Optional compliance (as per the Engineer's requirement) with accessibility standards (e.g., ADA)
Support Structure	Galvanized or powder-coated aluminum poles; available in 50 mm elliptical or 100 mm round profiles; decorative base cover optional for aesthetic integration
Other Features	• Synchronized flashing on both sides of the crossing • Automatic dimming based on ambient light • Audible alerts for visually impaired users • Bluetooth Low Energy communication

7.27.3. Construction Methods

- The RRFB system shall be installed in strict accordance with the approved Engineering drawings, manufacturer's instructions, and as directed by the Engineer.
- Each unit shall be mounted together with the appropriate pedestrian crossing warning sign and diagonal downward arrow plaque, as per MUTCD guidelines.
- For post-mounted installations, at least two RRFB units per crosswalk shall be installed; one on each approach. On divided highways, the left-side beacon shall preferably be mounted on the median.
- In the case of overhead-mounted units, the beacons must be positioned directly above or below the corresponding warning sign.
- All electrical and solar cabling shall be enclosed in UV- and weather-resistant conduit, with appropriate surge protection to guard against voltage spikes.
- Synchronization between beacons on both sides of a crosswalk shall be ensured using wired or wireless communications.

7.27.4. Operational Features and Flash Pattern

- RRFBs shall remain off (dark) until activated by a pedestrian via a push button or passive detection sensor.
- Upon activation, all beacons at a crossing shall begin synchronized flashing in a rapid alternating pattern, cycling every 800 milliseconds, with a simultaneous flash at the midpoint.
- The total flash duration must be based on pedestrian clearance time, and shall not exceed 5 flashes per second (5 Hz).
- If passive detection is used, the system shall automatically terminate the flash cycle once the pedestrian has cleared the crosswalk.

- The system shall feature automatic light intensity adjustment based on ambient brightness and support manual or scheduled remote activation/deactivation.

7.27.5. Power and Autonomy

- Solar-Powered Systems: Shall operate autonomously for at least 7 days without sunlight, assuming 400 activations per day at a 20-second flash duration.
- Hardwired Systems: Shall be connected to the grid using 120–240 VAC input, converted to 12 VDC via a certified converter.
- Hybrid Systems: Shall combine solar and grid sources with automatic switching for continuous operation during power failure or low sunlight conditions.
- All configurations shall include an energy management controller, battery charge regulator, and surge protection compliant with international electrical safety standards.
- The system must be capable of continuous operation in harsh weather conditions, including monsoons, heavy dust, and high humidity.

7.27.6. Measurement

The quantity of Rectangular Rapid Flashing Beacons (RRFB) shall be measured in units of complete assemblies, separately categorized based on their power configuration: (a) solar-powered, and (b) hybrid (solar + grid) systems. Measurement for RRFB shall be made based on the actual number of complete systems installed, tested, and accepted at designated locations, as shown on the Engineering drawings or as directed by the Engineer. Each measured unit shall include all components necessary for a fully functional and durable installation, including LED beacon units, side indicators, solar or hybrid power supply components, control box, activation devices (push button or passive detection), synchronization modules, communication hardware, galvanized or powder-coated poles, and all mounting and structural components.

The scope shall also include the construction of pole foundations, anchoring systems, base plates, embedded sleeves (if used), and any civil works required for secure and permanent installation. Associated works such as trenching, cabling, conduit installation, protection enclosures, grounding, and surge protection shall be deemed included. No separate measurement shall be made for these individual elements.

7.27.7. Payment

Payment shall be made at the contract unit rate per complete RRFB system, and shall constitute full compensation for the supply, delivery, installation, integration, civil works, testing, commissioning, and all incidental works required to deliver a fully operational system in accordance with the Specification.

Pay items shall be:

Pay Items	Description	Unit
7.27	Sensor-activated Rectangular Rapid Flashing Beacons (RRFB) flashing pedestrian crossing signal with adequate illumination and power backup.	
a	Solar-Powered	Number
b	Hybrid (Solar + grid) Systems	Number

7.28. Colored Pavement

7.28.1. General

This work shall consist of the supply, surface preparation, application, and final inspection and acceptance of high-performance acrylic surface coatings used as colored pavement treatments. These coatings are applied on existing asphalt or concrete surfaces to delineate specific roadway functions and enhance visibility, guidance, and traffic safety. Colored pavement is used to highlight areas such as bicycle lanes, transit lanes, toll collection zones, and pedestrian conflict areas. The material shall be water-based, environmentally friendly, and capable of withstanding vehicular traffic, weather exposure, and wear while maintaining strong adhesion, color stability, and adequate skid resistance. When applied within the traveled way to convey regulatory, warning, or guidance messages, colored pavement shall be considered a traffic control device and must conform to the applicable requirements of the Manual on Uniform Traffic Control Devices (MUTCD), 11th Edition.

7.28.2. Application

Colored pavements shall be applied in the following contexts, based on their intended function:

- Yellow-Colored Pavement: Used for areas separating traffic traveling in opposite directions, median islands, right-hand shoulders, and other regulatory applications.
- White-Colored Pavement: Applied on same-direction travel lanes, channelizing islands, and right shoulders.
- Green-Colored Pavement: Designated for bicycle lanes, conflict zones, and bicycle-priority crossings.
- Red-Colored Pavement: Used for exclusive transit lanes, including bus, BRT, and tram corridors.
- Purple-Colored Pavement: Reserved for Electronic Toll Collection (ETC) account-only lanes at toll plazas and open-road tolling zones.

In all cases, the colored pavement shall supplement, not replace, conventional road markings and must be used in conjunction with regulatory signage and appropriate longitudinal or transverse markings.

7.28.3. Materials and Technical Requirements

Colored pavement material shall be water-based acrylic with a minimum of 70% total solids and a viscosity between 85–95 Krebs ¹² Units. It must offer excellent adhesion, flexibility, and color retention, with minimal VOC (Volatile Organic Compound) content and environmental impact. The material shall be formulated for high durability under vehicular loading, provide effective glass bead retention for night visibility, and maintain non-bleeding, non-flammable, and non-toxic characteristics.

Colored pavements may be retro-reflective or non-retro-reflective, depending on their purpose. The materials used must be durable and capable of withstanding vehicle loads and environmental conditions. The surface must provide sufficient skid resistance and should minimize unexpected traction differentials between colored and non-colored areas. If additional retro-reflectivity is required, materials such as glass beads can be incorporated, though they should not significantly impact skid resistance.

Key Technical Specifications:

Property	Specification
Vehicle Type	100% Acrylic Binder – Water-based film-forming agent providing durability and adhesion
Total Solids	Minimum 70% by weight
Viscosity	85–95 Krebs Units (KU)
Dry-to-No-Pick-Up (Track-Free Time)	5 to 15 minutes at 15 mils wet film thickness
Water Resistance	Minimum 3 hours drying before moisture exposure at $\geq 50^{\circ}\text{F}$ (10°C) and $< 80\%$ RH
Spreading Rate	Approx. 300 linear feet per gallon for a 100mm-wide line

7.28.4. Operation and Performance

Colored pavement should supplement other pavement markings rather than replace them. It must contrast sufficiently with adjacent surfaces to ensure visibility. Additionally, patterns used in aesthetic applications must not distract or confuse road users.

For bicycle facilities, green-colored pavement is applied in a manner that maintains lane continuity while providing clear delineation of bike lanes. Transit lanes marked with red-colored pavement must

¹² Viscosity is expressed in Krebs Units (KU), a standard measurement obtained using a Stormer viscometer. A value of 85–95 KU indicates a medium-viscosity coating suitable for road surface application, offering optimal flow, film thickness, and coverage during spray or roller application.

include regulatory signage to indicate restrictions on general traffic. Similarly, purple-colored pavement for toll lanes must be flanked by appropriate longitudinal markings to guide vehicles toward designated lanes.

7.28.5. Measurement

Measurement for colored pavement shall be made in square meters based on the actual surface area treated and accepted by the Engineer. The measured quantity shall include surface preparation, application of coating, inclusion of reflective materials (if required), and any incidental work necessary to complete the item as per the Specification.

7.28.6. Payment

Payment shall be made at the contract unit rate, which shall be full compensation for surface preparation, supply, and application of the coating, incorporation of retro-reflective elements (if applicable), labor, equipment, tools, and all incidental work required to complete the work in accordance with this Specification and as directed by the Engineer.

Pay item shall be:

Pay Item	Description	Unit
7.28.1	Application of high-performance acrylic surface coating based on colored pavement (Yellow, White, Green, Red, or Purple)	Sq. meter

7.29. Skid Resistant Surface Treatment

7.29.1. General

This work shall consist of the application and performance verification of high-friction surface treatments (HFST) or equivalent skid-resistant systems designed to improve tire-pavement interaction, especially under wet or hazardous conditions. The treatments shall significantly enhance roadway safety by increasing pavement friction through the application of polymer-bonded high-friction aggregates. Skid resistance is determined by the pavement's microtexture and macrotexture, both of which play critical roles in reducing vehicle skidding, particularly in curves, intersections, approaches to pedestrian crossings, and steep grades.

7.29.2. Skid Resistance

Skid resistance performance is largely influenced by two surface characteristics: macrotexture and microtexture. Macrotexture refers to the broader, coarse-scale irregularities on the pavement surface,

which are shaped by the size, angularity, and distribution of the coarse aggregates, as well as by the construction methods used during surface placement. In contrast, microtexture encompasses the finer surface irregularities at the aggregate level and plays a critical role in maintaining friction, particularly in wet conditions. Microtexture durability is dependent on the inherent surface roughness of the aggregates and their resistance to polishing due to repeated vehicle loading and environmental exposure. To ensure adequate skid resistance, the pavement shall be designed and maintained with specific attention to both of these texture characteristics.

- Skid Resistance Value (SRV) is used in testing finished surfaces (like concrete or asphalt) for site-specific safety performance.
- Polished Stone Value (PSV) is used for assessing the aggregate used in surfacing materials—ensuring that it won't polish too much under traffic.

Skid Resistance Value (SRV)

Skid Resistance Value (SRV), measured using a pendulum test in accordance with BS EN 13036-4 or TRRL Road Note 27, indicates a surface's slip resistance, with higher SRV indicating better slip resistance.

Skid Resistance Values (SRVs) and calculated corresponding CoFs for different road conditions. The two measures of friction are related by the Equation: $\text{CoF} = (3 \times \text{SRV}) / (330 - \text{SRV})$. The minimum recommended values of skid resistance and calculated corresponding CoFs for different sites on road networks under typical wet conditions are shown in Table 7.9-1.

Table 7.29-1: Minimum recommended Skid Resistance Values for different road network sites, under wet conditions and measured using the British Pendulum Tester.

Type of Site	Minimum Recommended Skid Resistance Value (SRV)	Corresponding Coefficient of Friction (CoF)
Roundabouts	65.0	0.74
Bends with radius <150 m on unrestricted roads		
Gradients 1 in 20 or steeper, >100 m length		
Approaches to traffic lights on unrestricted roads		
Highways and heavily trafficked roads in urban areas (>2000 vehicles/day)	55.0	0.6
All other sites	45.0	0.47

Polished Stone Value (PSV)

Polished Stone Value (PSV) reflects the resistance of aggregates to polishing by traffic, with higher values indicating better ability to retain microtexture and thus maintain skid resistance over time. As per CD 236 (DMRB 7.5.1), the PSV requirement is directly tied to traffic category and the type of site.

For high-risk zones (e.g., sharp turns, pedestrian access near booths), a minimum PSV value of 65 is specified. However, with a higher amount of cumulative vehicles/lane/day, PSV 68+ is often preferred, and the recommendation is to use High Friction Surfacing (HFS) for 3000+ cumulative vehicles/lane/day.

Where a material is labeled as “68+” in standards, it must comply with the requirement that none of the last three PSV tests fall below 68.

Limestone aggregates shall not be used where PSV specifications are applied, unless performance data justifies it under similar traffic and environmental conditions.

Aggregates must also comply with the maximum Aggregate Abrasion Value (AAV) limits to ensure resistance to wear. For toll plaza applications, the AAV shall not exceed the values recommended in Table 7.34-3 (adapted from Table 3.10 of CD 236).

Table 7.29-2: Maximum AAV of chippings, or coarse aggregates in unchipped surfaces, for new surface courses, excluding pavement quality concrete.

Traffic (cv/lane/day) at design life	≤ 250	251 - 1000	1001 - 1750	1751 - 2500	2501 - 3250	> 3250
Max. AAV for chippings for Hot Rolled Asphalt, surface dressing, slurry/micro-surfacing system	14	12	12	10	10	10
Max. AAV for aggregate in thin surface course system, exposed aggregate concrete surfacing	16	16	14	14	12	12

7.29.3. Materials and Applications for High Friction Surface Treatment

An effective method to achieve high skid resistance is the application of High Friction Surface Treatments (HFST). HFST involves applying a thin layer of high-quality, polish-resistant aggregate, such as calcined bauxite, embedded in a polymer binder to the pavement surface. This treatment significantly enhances friction, aiding motorists in maintaining better control in both dry and wet driving conditions. HFST is particularly beneficial in areas prone to skidding incidents, such as sharp curves, intersections, and steep grades.

High-Friction Aggregate

The primary material used in High Friction Surface Treatment (HFST) is high-quality, polish-resistant aggregate that enhances skid resistance. The selection of aggregate is critical to ensuring long-term friction performance, particularly in areas with high traffic volumes.

- Preferred Aggregate Type: Calcined Bauxite (due to its high hardness and resistance to polishing)
- Aggregate Size: 1-3 mm (to ensure optimal texture depth and durability)
- Aggregate Hardness: Mohs scale of hardness ≥ 9 (ensuring minimal wear)
- Aggregate Polish Stone Value (PSV): ≥ 68 (indicating strong resistance to polishing and maintaining long-term friction)
- Aggregate Absorption: $\leq 2\%$ (to prevent binder weakening and maintain durability)

Binder Systems

The aggregate must be embedded into a high-performance binder to ensure strong adhesion to the pavement. Several binder types can be used based on environmental conditions and traffic load.

- Epoxy Resin Binder:
 - Tensile Strength: ≥ 10 MPa
 - Viscosity: 2000-5000 cP at 25°C
 - Pot Life: 20-40 minutes
 - Curing Time: 4-6 hours at 25°C
 - Service Life: 8-12 years
- Methyl Methacrylate (MMA) Binder:
 - Curing Time: 30-90 minutes (depending on ambient temperature)
 - Adhesion Strength: ≥ 2 MPa
 - UV Stability: High (resistant to yellowing and degradation)
 - Crack Resistance: Excellent
- Polyurethane Binder:
 - Curing Time: 2-4 hours
 - Chemical Resistance: High (suitable for industrial applications)
 - Flexibility: Moderate (useful for surfaces subject to temperature fluctuations)

Skid Resistance Performance Metrics

To evaluate the effectiveness of skid-resistant treatments, specific performance criteria must be met.

- Skid Resistance Factor (SRF): Measured using a British Pendulum Tester or Dynamic Friction Tester

- Dry Condition: SRF ≥ 0.80
- Wet Condition: SRF ≥ 0.65
- Mean Texture Depth (MTD):
 - Fresh Application: ≥ 1.4 mm
 - After 3 years of service: ≥ 1.2 mm
- Friction Coefficient (ASTM E1911 Standard)
 - New Surface: ≥ 0.75
 - After 5 years: ≥ 0.60
- Temperature Resistance:
 - Operating Range: -30°C to 60°C (varies based on binder type)
 - Freeze-Thaw Durability: Must withstand 300+ cycles with minimal degradation

Application & Durability Considerations

The surfacing shall exhibit no delamination or aggregate loss under normal traffic loading for a minimum of 5 years.

Standards and Compliance

The application of High Friction Surface Treatments (HFST) and skid-resistant coatings is based on guidelines from the Federal Highway Administration (FHWA), Florida Department of Transportation (FDOT), and industry best practices outlined by the High Friction Surface Treatment Association (HFSTA). The materials, including calcined bauxite aggregates and polymer-based binders, are specified to meet the performance standards for friction enhancement and durability in accordance with FHWA recommendations (FHWA-SA-12-019) and state DOT specifications.

7.29.4. Construction Requirements

- The surface shall be cleaned and prepared as per the manufacturer's recommendation, ensuring it is free of moisture, dust, oils, or loose particles.
- Application shall follow manufacturer's specifications for binder-to-aggregate ratio, spread rate, and curing time.
- Minimum coating thickness: as per product datasheet, typically 3–5 mm.
- Application temperature shall be between 10°C and 40°C unless otherwise recommended and shall not proceed in ambient temperatures below 5°C or during precipitation.
- After curing, excess aggregate shall be removed, and the surface shall be inspected for uniformity and coverage.
- The finished surface shall achieve a Skid Resistance Value (SRV) ≥ 68 , tested using the British Pendulum Tester in accordance with BS EN 13036-4.

7.29.5. Measurement

Measurement for Skid Resistant Surface Treatment shall be made in square meters of pavement surface completed, tested, and accepted in accordance with this Specification and the Engineering drawings. The measured area shall include all associated works such as surface preparation, binder application, aggregate spreading, removal of excess material, and post-application skid resistance testing. No separate measurement shall be made for materials, trial areas, or temporary protection works. Only areas achieving the specified Skid Resistance Value (SRV) and accepted by the Engineer shall be considered for payment.

7.29.6. Payment

Payment shall be deemed to include full compensation for surface cleaning, supply and application of binder and aggregate, finishing, testing, and all labor, equipment, tools, and incidental works necessary to complete the item in accordance with the Specification.

Pay item shall be:

Pay Item	Description	Unit
7.29.1	High Friction Surface Treatments (HFST)	Sq. meter

7.30. Terminal Protection System (SKT-SP and FLEAT-SP Types)

7.30.1. General

This work shall consist of the supply, installation, and commissioning of guardrail terminal systems of the SKT-SP (Sequential Kinking Terminal - Standard Post) and FLEAT-SP (Flared Energy Absorbing Terminal - Standard Post) types at designated roadside locations. These systems are designed to mitigate the severity of vehicle impacts at guardrail ends by absorbing or redirecting collision energy. Both SKT-SP and FLEAT-SP systems shall comply with NCHRP Report 350 Test Level 3 (TL-3: 100 km/hr) and Test Level 2 (TL-2: 70 km/hr) crash performance criteria and be approved for use as energy-absorbing terminals for W-beam guardrail systems in accordance with AASHTO Roadside Design Guide.

7.30.2. SKT-SP and FLEAT-SP Terminals

SKT-SP (Sequential Kinking Terminal – Standard Post):

A tangent, energy-absorbing guardrail end terminal that dissipates vehicle impact energy by sequentially kinking the W-beam rail as the impact head slides along it. It aligns directly with the roadway and is suitable for straight installations without requiring a lateral offset.

FLEAT-SP (Flared Energy Absorbing Terminal – Standard Post):

A flared, energy-absorbing guardrail end terminal designed to reduce head-on impacts by offsetting the terminal from the traffic lane. It absorbs impact energy by kinking the rail and requires a straight flare installation with a specific lateral offset over its length.



SKT-SP Terminal



FLEAT-SP Terminal

Figure 7.30-1: Terminal protection system (SKT-SP and FLEAT-SP Types)

7.30.3. Components and Design

- System Length:
 - SKT-SP: Typically, 50 ft (15.24 m) for TL-3 applications; other configurations include 12.5 ft (3.81 m), 25 ft (7.62 m), and 37.5 ft (11.43 m).
 - FLEAT-SP: Typically, 37.5 ft (11.43 m) for TL-3; other options include 12.5 ft (3.81 m) and 25 ft (7.62 m).
- Post Configuration: Both systems use hinged steel posts at positions #1 and #2, and standard W6x9# or W6x8.5#¹³ steel guardrail posts at positions #3 and beyond, spaced at 1.905 m (6'-3") centers.
- Impact Head: Constructed from high-strength steel, featuring a sliding impact head that absorbs kinetic energy through sequential kinking (SKT) or flaring and redirection (FLEAT).
- Anchor Assembly: Includes a universal cable anchor bracket, bearing plate, and tensioned steel cable secured through post #1.
- Flare Geometry:

¹³ These refer to wide-flange I-beams that are approximately 6 inches deep, with the W6x9# weighing 9 pounds per foot and the W6x8.5# weighing 8.5 pounds per foot.

- o SKT-SP: Optional straight flare with 0–2 ft (0–0.61 m) offset over 50 ft (15.24 m).
- o FLEAT-SP: Required straight flare with 2.5–4 ft (0.76–1.22 m) offset over 37.5 ft (11.43 m).

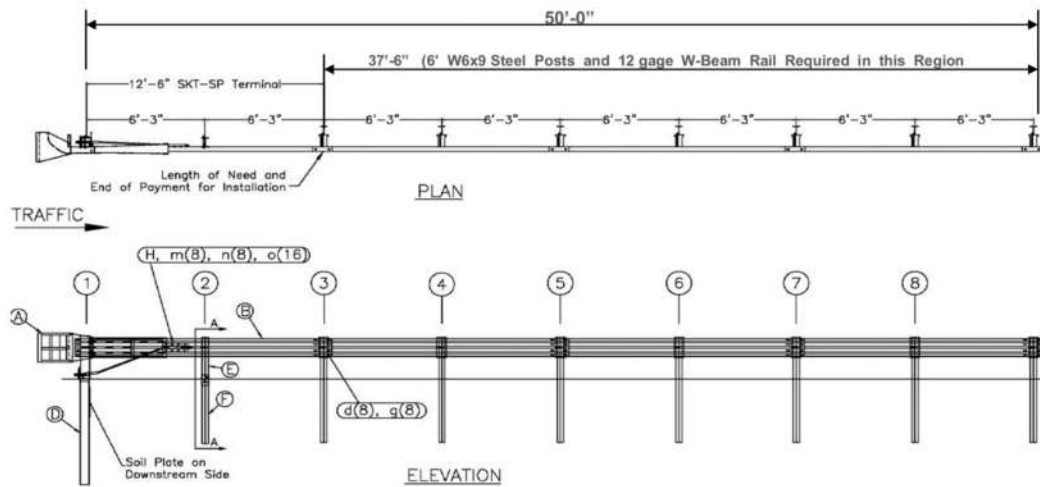


Figure 7.30-2: Plan and elevation of standard SKT-SP system.

Source: Lindsay Transportation Solutions, Product Catalogue (2023), SKT-SP Tangential Terminal and FLEAT-SP Flared Terminal specifications.

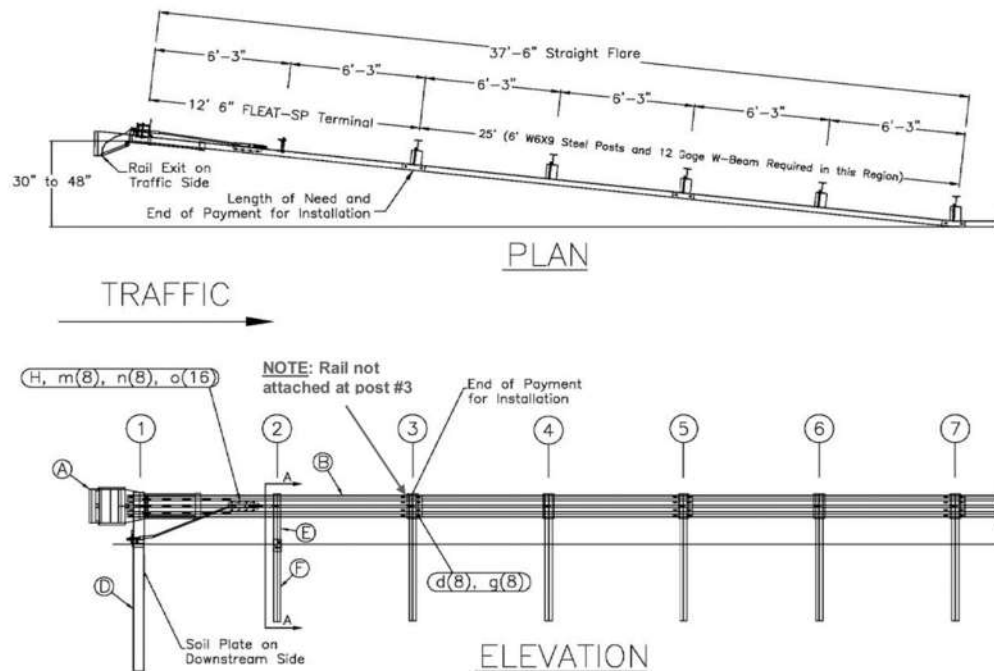


Figure 7.30-3: Plan and elevation of standard FLEAT-SP system.

Source: Lindsay Transportation Solutions, Product Catalogue (2023), SKT-SP Tangential Terminal and FLEAT-SP Flared Terminal specifications.

7.30.4. Materials

- **Impact** heads, posts, and cable components shall be galvanized or painted in accordance with ASTM A123 or an equivalent corrosion protection standard.
- All fasteners used in the system shall comply with the mechanical and dimensional requirements of ASTM A325.
- Steel posts and anchor brackets shall meet or exceed the mechanical properties specified by the manufacturer and relevant national or AASHTO standards.
- The SKT-SP and FLEAT-SP systems allow for a variety of post material configurations, depending on design requirements and site conditions. These include:
 - Standard steel guardrail posts, designated as W6x9# or W6x8.5#, typically 6'-0" (1.83 m) in length.
 - Long or medium hinged steel posts, approximately 8.5 ft (2.59 m) or 6 ft (1.83 m) long, used at breakaway locations (#1 and #2).

- Plug-welded steel posts, either medium (6 ft) or short (3.5 ft) lengths, often preassembled and used with foundation tubes.
- CRT (Controlled Release Terminal) wood posts, measuring 6" x 8" x 6'-0" (152 x 203 x 1830 mm) with dual breakaway holes.
- BCT (Breakaway Cable Terminal) wood posts, measuring 5.5" x 7.5" x 3'-9" (140 x 190 x 1140 mm) with a single breakaway hole, installed in foundation tubes.
- Steel foundation tubes used at hinged post locations may be 6 ft (1.83 m) long (no soil plate) or 4.5–5 ft (1.37–1.52 m) long with soil plates; for SKT-SP, foundation tubes may also be used at posts #3 and beyond.
- The SKT & FLEAT Universal Cable Anchor Bracket shall be a pre-engineered assembly designed to anchor the tension cable securely at post #1. It includes:
 - A high-strength steel bracket, pre-drilled for shoulder bolts.
 - Eight ½" A325 structural bolts with washers and nuts, ensuring tight and secure anchorage to the W-beam guardrail.
 - The bracket must be fully seated on the shoulder bolts during installation to ensure proper force transfer during an impact event.

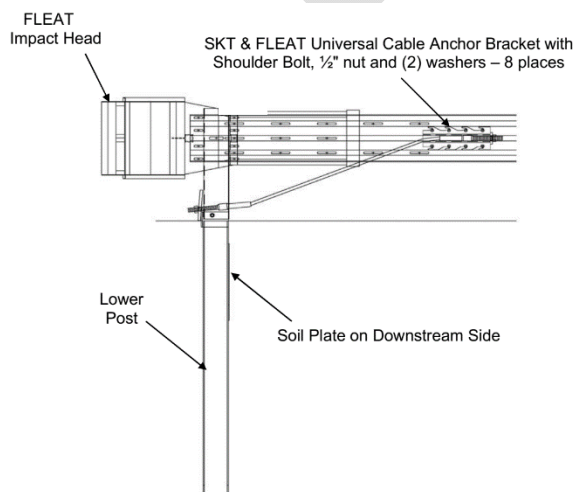


Figure 7.30-43: Typical assembly of FLEAT-SP system.

Source: Lindsay Transportation Solutions, Product Catalogue (2023), SKT-SP Tangential Terminal and FLEAT-SP Flared Terminal specifications.

7.30.5 Installation

Site Preparation

Before installation begins, ensure the area is properly assessed and cleared. For SKT-SP systems placed parallel to the roadway shoulder, a flare with a slope of 25:1 or gentler is advised to prevent the impact head from projecting into the shoulder area, thereby minimizing unintended activations. This flare is not mandatory and can be reduced or omitted depending on site constraints.

The FLEAT-SP system requires a straight flare configuration with a lateral offset ranging from 2'-6" to 4'-0" (0.76 m to 1.22 m) over its full system length of 37'-6" (11.43 m), with a 4'-0" (1.22 m) offset being standard unless otherwise indicated in the contract documents. Site grading must be performed where necessary to ensure the lower segments of the breakaway posts remain no more than 4 inches (100 mm) above the ground surface, as per AASHTO guidance.

Installation Steps

1. Setting Standard Posts (#3 and beyond):

All posts beginning from Post #3 onward shall be constructed using W6x9# standard wide-flange steel sections. These posts are to be spaced at consistent 6'-3" (1.905 meters) centers in alignment with highway guardrail standards and the system layout.

The installed height of the guardrail, measured from the edge of the shoulder or finished ground level to the top of the W-beam rail, should be approximately 27¾ inches (705 mm), with a maximum allowable height of 30 inches (762 mm).

- For SKT-SP installations with a 50 ft (15.24 m) pay limit configuration, the standard steel posts shall be placed at positions #3 through #8.
- For FLEAT-SP installations with a 37.5 ft (11.43 m) configuration, posts shall be set from #3 through #7.

Each post must be vertically aligned and driven to the proper depth so that the finished rail elevation remains uniform along the terminal section. Care must be taken to ensure post placement adheres to the alignment and grade shown in the approved Engineering drawings.

2. Installing Breakaway Posts (#1 and #2):

Breakaway posts located at positions #1 and #2 are composed of two-part hinged steel posts designed to separate under impact. These posts must be assembled from the ground up, beginning with the installation of the lower segment before connecting the upper portion. Under no circumstance should the lower section be driven with the upper segment pre-attached, as this may result in mechanical deformation or improper alignment.

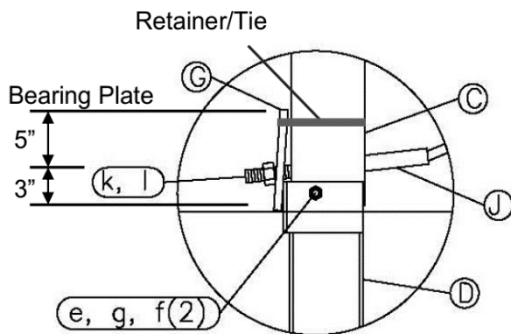
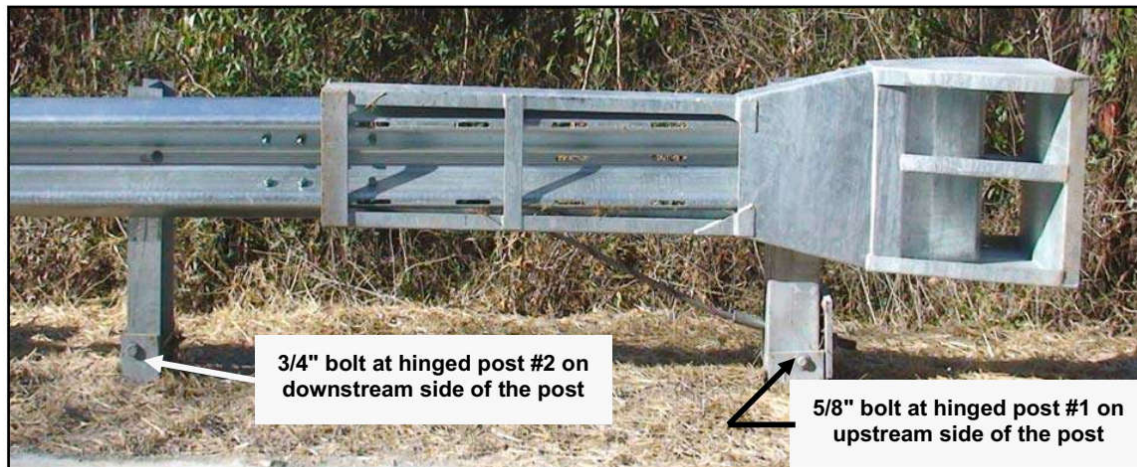
Unlike traditional terminal systems, the SKT-SP and FLEAT-SP do not require a ground line strut, and post spacing must be maintained at 6'-3" (1.905 m) between centers to ensure conformity with the system's geometry.

Post #2 Configuration:

- Both upper and lower segments of Post #2 consist of W6x9# steel sections.
- These components are joined using a $\frac{3}{4}$ inch x 8 $\frac{1}{2}$ inch (19 mm x 216 mm) hex bolt and nut. A $\frac{3}{4}$ inch x 8 inch (203 mm) hex bolt is also acceptable if specified.
- The hinge bolt on the lower segment must be placed on the downstream side, opposite the impact head.
- The upper segment features an open-ended slot, which should face upstream, toward the direction of the impact head.

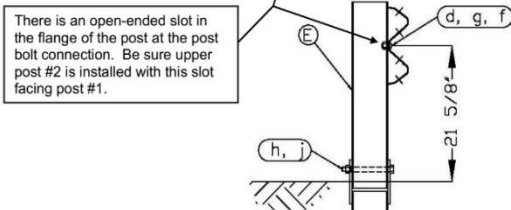
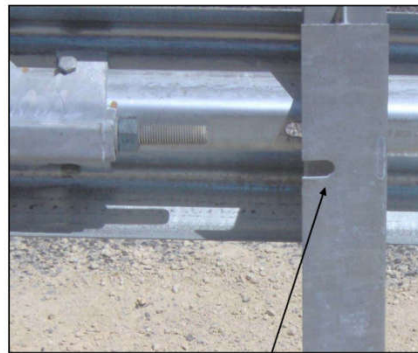
Post #1 Configuration:

- The upper portion of Post #1 consists of a 6-inch x 6-inch x $\frac{1}{8}$ inch (152 mm x 152 mm x 3.2 mm) square steel tube.
- The lower portion is a W6x15# steel section equipped with a welded soil plate for stability.
- Join the two segments using a $\frac{5}{8}$ inch x 9-inch (15.9 mm x 229 mm) hex bolt with nut and two washers.
- The hinge bolt must be oriented upstream, facing the impact head.
- The soil plate must be installed on the downstream side, facing away from traffic.



C	Upper Post #1 Tube 6" x 6"
D	Lower Post #1 W6" with Soil Plate
G	Bearing Plate & Retainer/Tie
J	Cable Anchor Assembly
e	5/8" x 9" Hex Bolt
f	5/8" Washer
g	5/8" Nut
k	1" Nut
l	1" Washer

(SKT-SP shown. FLEAT-SP details similar.)



E	Upper Post #2 W6"
d	5/8" x 1 1/4" Guardrail Splice Bolt
f	5/8" Washer
g	5/8" Nut
h	3/4" x 8 1/2" Hex Bolt
j	3/4" Nut

NOTE: Be sure the 3/4" x 8 1/2" hex bolt at Hinged Post #2 is on the downstream side of the post (toward post #3).

Post#1

Post#2

Figure 7.30-5: Post #1 and post #2 connection details.

Source: Lindsay Transportation Solutions, Product Catalogue (2023), SKT-SP Tangential Terminal and FLEAT-SP Flared Terminal specifications.

After installation, the top of the lower stubs for both Posts #1 and #2 should not extend more than 4 inches (100 mm) above finished ground level, as verified by the AASHTO 5-foot cord method. If the protrusion exceeds this limit, grading or reinstallation is required to achieve compliance.

- For dense or compact soils, a pilot hole may be drilled, followed by driving the lower post using impact or vibratory equipment. Care must be taken to avoid contact with side plates during driving operations.
- Alternatively, posts may be installed by augering and backfilling. In this method, the hole must be wide enough to allow effective compaction of the backfill, minimizing risk of post settlement or lateral movement.
- If rock is encountered, installation shall proceed in accordance with relevant State specifications, as guidance may differ between jurisdictions.

3. Guardrail Installation:

Begin the guardrail installation by attaching standard W-beam panels (12 ft 6 in (3.81 m) or 25 ft 0 in (7.62 m) in length) downstream of Post #3. The SKT-SP or FLEAT-SP end section of the guardrail should then be connected to span from Post #1 to Post #3 for a 12'-6" (3.81 m) configuration or from Post #1 to Post #5 for a 25'-0" (7.62 m) configuration.

In most cases, a universal end panel with 6'-3" (1.905 m) post spacing is provided. This panel can be identified by the presence of:

- Eight holes with $\frac{3}{4}$ inch (19 mm) diameter, intended for attaching the cable anchor bracket, and
- Thirteen slots of $\frac{1}{2}$ inch x 4-inch (13 mm x 102 mm) size, with ten slots located in the rail corrugations and three slots located in the valleys.

Depending on the system type:

- The SKT-SP may use an end panel that includes only the three valley slots ($\frac{1}{2}$ " x 4").
- The FLEAT-SP may utilize an end panel with only the ten corrugation slots ($\frac{1}{2}$ " x 4").

All subsequent W-beam panels used in either system must be consistent with standard highway guardrail specifications, maintaining a post spacing of 6'-3" (1.905 m).

For FLEAT-SP installations, the required flare offset is achieved by joining the guardrail panels and then manually adjusting the alignment backward. No factory bending or cold-curving of the rail is needed. Panel joints must be fastened using $\frac{5}{8}$ inch x 1 $\frac{1}{4}$ inch (15.9 mm x 32 mm) Highway Guard Rail (H.G.R.) bolts with matching $\frac{5}{8}$ inch (15.9 mm) H.G.R. nuts.

Guardrail-to-post connections vary by system:

- In SKT-SP, the guardrail is attached to posts and blockouts beginning at Post #3, using $\frac{5}{8}$ inch x 10-inch (15.9 mm x 254 mm) H.G.R. bolts and nuts.
- In FLEAT-SP, attachment with blockouts starts from Post #4 onward.
- Posts #1 and #2 in both systems are not fitted with blockouts, and no post bolt is installed at Post #1 under any condition.
- The end rail panel in both systems is connected to Post #2 using a $\frac{5}{8}$ inch x $1\frac{1}{4}$ inch (15.9 mm x 32 mm) H.G.R. bolt and nut.

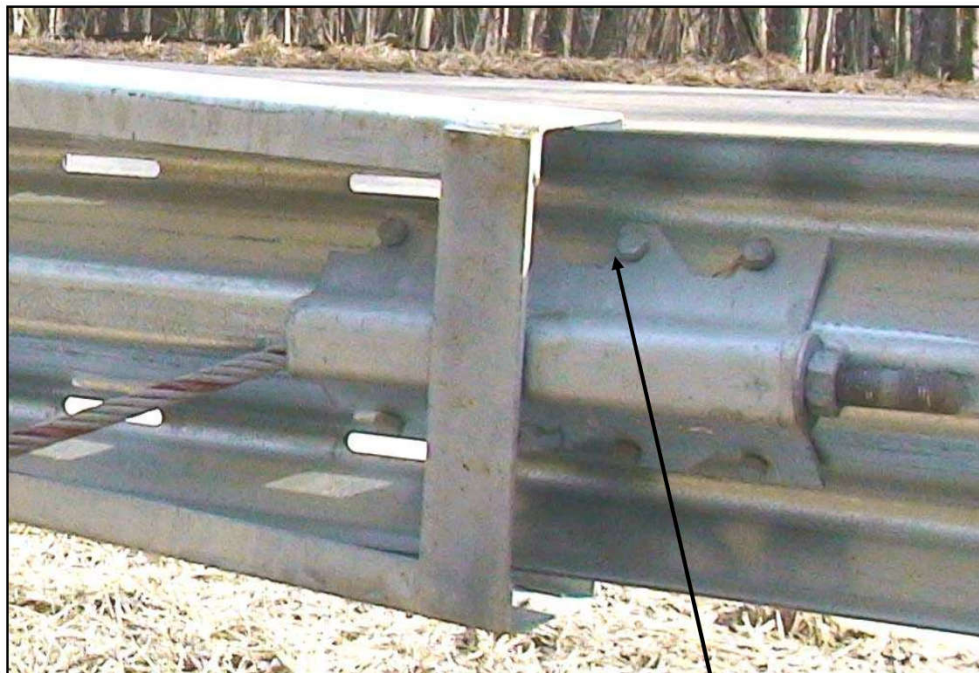
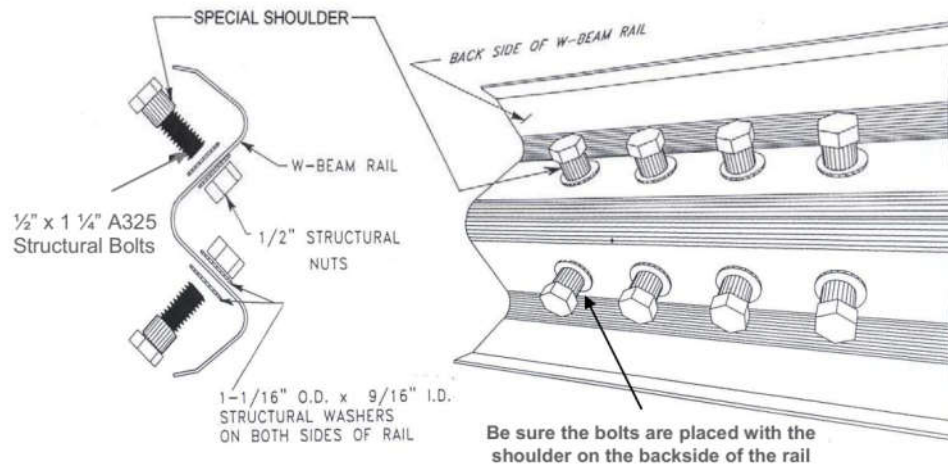
All W-beam rails used within the terminal section of both SKT-SP and FLEAT-SP systems must remain entirely straight. No bending or curving of the guardrail within the terminal length is permitted.

4. Cable Anchor Bracket Installation:

The installation of the cable anchor bracket begins with attaching eight $\frac{1}{2}$ inch (12.7 mm) diameter shoulder bolts to the end section of the W-beam guardrail. Each bolt must be secured using two structural washers, having an outer diameter (OD) of 1-1/16 inches (27 mm) and an inner diameter (ID) of 9/16 inches (14.3 mm), positioned on both sides of the rail section. These are fastened in place using $\frac{1}{2}$ inch (12.7 mm) structural nuts.

It is critical that the shoulders of all bolts are oriented on the rear side of the guardrail, facing away from the direction of traffic, to ensure proper force distribution and engagement with the anchor bracket during impact loading.

To facilitate accurate alignment, the shoulder bolts should initially be tightened only to a finger-tight level. Once installed, position the cable anchor bracket by aligning its pre-slotted openings with the protruding shoulders of the bolts. Lightly tap the bracket into place using a hammer until it fully seats on the shoulders. After correct positioning is confirmed, use a wrench to fully tighten all nuts, ensuring a secure and rigid connection. The welded reinforcing plate on the rear face of the anchor bracket must face toward Post #2, consistent with the bracket's design orientation and crash-tested configuration.



It is important that the anchor bracket be fully seated on the shoulder portion of the cable anchor bolts

Figure 7.30-6: Installation of cable anchor bracket.

Source: Lindsay Transportation Solutions, Product Catalogue (2023), SKT-SP Tangential Terminal and FLEAT-SP Flared Terminal specifications.

5. Impact Head Installation:

Prior to mounting the impact head, ensure that the cable anchor bracket and eight ½ inch (12.7 mm) diameter shoulder bolts are properly installed on the terminal end of the W-beam guardrail. This

anchoring assembly must be firmly secured to ensure proper alignment and energy transfer during an impact.

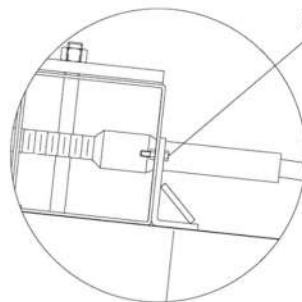
For FLEAT-SP systems, the impact head's rail exit slot must face the traffic side of the installation to allow correct redirection of impacting vehicles. For both SKT-SP and FLEAT-SP, the impact head's feeder guide chute is to be carefully positioned over the terminal end of the W-beam rail, with the tubular guide directed away from traffic—that is, oriented toward the back side of the guardrail system.

Slide the impact head forward along the W-beam until the mounting flanges of the head align with the bolt holes on Post #1, which is fabricated from a 6-inch x 6-inch x $\frac{1}{8}$ inch (152 mm x 152 mm x 3.2 mm) steel tube section. Once in position, secure the impact head to Post #1 using two $\frac{5}{16}$ -inch x 1-inch (7.9 mm x 25 mm) hex bolts. Each bolt must be installed with a corresponding nut and two flat washers—one placed on each side of the top and bottom post angle connections.

For improved visibility during nighttime or low-light conditions, it is recommended that the front face of the impact head be marked with a reflective object marker that conforms to applicable state or national standards. This object marker enhances driver recognition and terminal visibility but may not be included in standard system deliveries unless explicitly stated in the project specifications or contract documents.



(SKT-SP shown. FLEAT-SP details similar.)



5/16" x 1" hex bolt w/ nut &
(2) washers – 2 places

Figure 7.30-7: Impact head connection details.

Source: Lindsay Transportation Solutions, Product Catalogue (2023), SKT-SP Tangential Terminal and FLEAT-SP Flared Terminal specifications.

6. Cable Assembly Installation:

The cable assembly must be installed by first routing it through the cable anchor bracket and then passing it through the opening at the base of Post #1. For installations using the SKT-SP system, the cable shall also be guided through the interior of the impact head's feeder chute, ensuring correct alignment with the energy-absorbing components. In contrast, for the FLEAT-SP configuration, the cable must bypass the feeder chute and be routed directly to the anchoring point without passing through it.

At the base of Post #1, position the bearing plate so that the 5-inch (127 mm) side is facing upward and the 3-inch (76 mm) side is facing downward, in accordance with the system layout. The plate must be fixed in place using a retaining tie or clip to prevent it from rotating or shifting during service.

To secure the cable assembly, thread a 1-inch (25.4 mm) hex nut and washer onto each cable end. As the nut is tightened, gently tap the downstream side of the cable anchor bracket using a mallet or hammer to ensure that the bracket fully engages with the shoulder bolts. This action helps eliminate any slack and confirms that the bracket is firmly seated.

While tightening the nut, the cable must be held in place using vice grips or locking pliers on the opposite end to prevent rotation and avoid internal twisting. The cable should be tensioned until it is firm and free of sag.

It is essential to verify that the cable anchor bracket is completely seated on the shoulder bolts once the installation is finished. Proper engagement of these components is critical to the system's structural integrity and energy dissipation function during a vehicle impact.

7.30.6. Inspection

All installed SKT-SP and FLEAT-SP terminals shall be inspected upon completion and periodically thereafter to ensure continued compliance with functional and safety requirements. Key inspection criteria include:

- Guardrail height shall be approximately 27¾ inches (705 mm), not exceeding 30 inches (762 mm) above finished grade.
- All post spacing must be maintained at 6'-3" (1.905 m) centers.
- The impact head shall be correctly oriented and securely fastened to Post #1.
- Cable anchor bracket must be fully seated on all shoulder bolts, and the cable assembly shall be taut.
- No rail curvature is permitted within the terminal length; all W-beam sections must remain straight.
- Posts #1 and #2 must not extend more than 4 inches (100 mm) above the ground line; verify using a 5-foot (1.52 m) straightedge in accordance with AASHTO guidelines.
- Ensure object marker visibility on the impact head (if required by contract documents).

7.30.7. Repair

Following a vehicle impact or when damage is detected during inspection, the SKT-SP or FLEAT-SP terminal shall be evaluated and repaired to restore its functional performance. The repair process shall follow the steps below:

- Inspect the impact head for signs of damage or detachment. Replace it with the same type and model if necessary.
- Check the cable assembly, including the cable, nuts, washers, bearing plate, and anchor bracket. Replace any component that is bent, corroded, or otherwise compromised.
- Assess posts, blockouts, and fasteners for damage. Replace broken or severely bent elements. Salvage of undamaged parts is permitted with the Engineer's approval.
- Remove kinked rail sections using a torch or mechanical cutter. If the impact head is stuck, use a chain to gently pull it free, ensuring adjacent rail sections remain stable.
- Disconnect and remove damaged guardrail panels, taking care to preserve reusable parts.
- Replace damaged posts: Unbolt and remove hinged posts (#1 and #2); extract standard posts (#3 and beyond) using suitable methods. Backfill and compact any disturbed soil to prevent settlement.
- Reinstall the terminal system per the original installation specifications. All replacement parts must match the original in type, size, and performance rating.

Upon completion, all repairs must be reviewed and approved through a final inspection before the terminal is returned to service.

7.30.8. Measurement

Measurement for the Terminal Protection System, whether SKT-SP or FLEAT-SP, shall be made on a per-unit basis, corresponding to each terminal that has been fully installed, tested, and accepted at the specified location as shown in the Engineering drawings or as directed by the Engineer. Each unit measured for payment shall represent the complete assembly and installation of the terminal system, including but not limited to all breakaway and standard steel posts, the impact head assembly, universal cable anchor system (including the cable, anchor bracket, bearing plate, nuts, washers, and bolts), and guardrail end panels appropriate to the terminal type. The measurement shall also include all splicing hardware, blockouts (where applicable), as well as all site preparation, such as excavation, grading, and compaction, necessary to achieve proper embedment, alignment, and height of the installed components. No separate measurement shall be made for individual components, labor, equipment, or any incidental works required to deliver a complete and functional terminal installation in accordance with the Specifications and Engineering drawings.

7.30.9. Payment

Payment shall include full compensation for supply, installation, hardware, labor, tools, transportation, grading, fittings, and all other works necessary to install the terminal system in accordance with the Specifications and Engineering drawings.

Pay items shall be

Pay Item	Description	Unit
7.30.1	Sequential Kinking Terminal - Standard Post (SKT-SP)	Number
7.30.2	Flared Energy Absorbing Terminal - Standard Post (FLEAT-SP)	Number

7.31. Flashing Beacon for Supplemental Warning/Intersection Control

7.31.1. General

This work shall consist of supplying, installing, testing, and commissioning Flashing Beacons at designated locations to enhance traffic safety by providing supplemental warning or intersection control. Flashing Beacons are traffic signaling devices equipped with one or more signal indications operating in a flashing mode to draw attention and alert drivers to specific road conditions or intersection approaches. The beacons shall comply with the Manual on Uniform Traffic Control Devices (MUTCD), 11th Edition, and shall also conform to the relevant provisions adapted from and included in the RHD Road Safety Manual 2024.

7.31.2. Types and Application of Flashing Beacons

Stop Beacon

Stop Beacons are used to enhance the visibility of STOP, DO NOT ENTER, or WRONG WAY signs, particularly at critical or high-risk locations. They use flashing red signals to indicate that drivers must come to a complete stop. When multiple beacons are installed in horizontal alignment, the lights flash simultaneously; when vertically aligned, they flash alternately to avoid confusion with railroad signals.

Warning Beacon

Warning Beacons supplement warning or regulatory signs by drawing additional attention to potential hazards or conditions such as sharp curves, mid-block pedestrian crossings, and accident-prone areas like crest curves or intersections. These beacons flash yellow and are typically operated only during periods when the condition exists, enhancing situational awareness for road users.

Speed Limit Sign Beacon

Speed Limit Sign Beacons are used to reinforce posted speed limits, especially in time-dependent zones such as school areas or temporary construction zones. They feature flashing yellow lights located near the speed limit sign to indicate that the regulation is in effect. These beacons can operate continuously or during preset hours, depending on the application.

Intersection Control Beacon

Intersection Control Beacons are installed at intersections where full traffic signals are not justified, but additional visibility is needed due to crash history or geometric complexity. They provide a flashing yellow signal on the major roadway to alert drivers to proceed with caution and a flashing red signal on minor approaches controlled by STOP signs.

Rectangular Rapid-Flashing Beacon (RRFB)

See Section 7.27.

Hybrid Beacons

Hybrid Beacons are specialized devices designed to manage pedestrian or emergency vehicle crossings at unsignalized locations. These beacons remain dark when inactive and display a combination of steady and flashing lights when triggered.

- **Pedestrian Hybrid Beacon (PHB):** Installed at marked crosswalks, PHBs help pedestrians cross by activating a signal sequence: flashing yellow, steady yellow, steady red, and alternating flashing red. This sequence informs drivers to yield and then stop.
- **Emergency-Vehicle Hybrid Beacon:** Used to facilitate the safe entry of emergency vehicles from unsignalized driveways or station exits. These beacons are activated remotely by authorized personnel and instruct approaching motorists to stop or yield through a sequence of signal indications.

7.31.3. General Requirements

The installation, operation, and performance of flashing beacons shall adhere to the following general requirements:

- Flashing beacons shall consist of one or more signal sections from a standard traffic signal face, displaying flashing CIRCULAR YELLOW or CIRCULAR RED indications, as appropriate for the application.
- Beacons shall be installed only at locations where they supplement regulatory or warning signs or provide intersection control where conventional traffic signals are not warranted.
- The flashing rate shall be between 50 and 60 flashes per minute, with the illuminated period of each flash lasting between 50% and 67% of the total cycle.
- Signal indications shall be either 200 mm or 300 mm in nominal diameter. 300 mm indications shall be used where the posted or 85th-percentile approach speed exceeds 60 km/h, and the beacon is post-mounted without overhead support.

- When multiple signal indications are used, horizontally aligned signals shall flash simultaneously and vertically aligned signals shall flash alternately, to avoid confusion with railroad grade crossing signals.
- The edge of the signal housing shall be not less than 300 mm and not more than 600 mm from the nearest edge of the associated sign (e.g., STOP, SPEED LIMIT, DO NOT ENTER) or supplementary boards.
- Flashing beacons shall not be mounted within the border of a sign, except where permitted (e.g., Interchange Exit Direction signs with advisory speed panels).
- Beacons shall operate only during the periods when the condition or regulation exists (e.g., school hours, peak pedestrian periods), unless continuous operation is justified by site conditions.
- Audible information devices can be included with pedestrian-actuated warning beacons to aid visually impaired users. These devices shall not use vibrotactile or percussive signals.

7.31.4. Materials and Components

The flashing beacon shall meet the following specifications:

Component	Specification
Blinker Size	300 mm (12 Inch) & 200 mm (8 Inch), circular design
Body Material	Molded polycarbonate or black powder-coated, vandal-resistant aluminum, suitable for extreme weather conditions
Lens	UV-stabilized, transparent polycarbonate
Gasket	Rubber gasket for sealing between the lens and the signal unit
Color Options	Red / Amber / Green
LED & PCB	Ultra-bright, water-clear LEDs mounted on 1.5 mm thick glass epoxy PCB; minimum 120 LEDs; viewing angle 24°
Light Intensity	Meets SAE J595 Class 1 standards (for enhanced brightness and visibility)
Power Factor	>0.9
Visibility	Minimum 500 meters, even in poor weather conditions
Charge Control Unit (CCU)	Built-in intelligent controller; protects against deep discharge, overcharge, and reverse voltage; includes surge protection
Solar Panel	High-efficiency monocrystalline/polycrystalline panel; 12V, 30–50W capacity; 360° adjustable mounting; CE & IEC certified
Battery System	Sealed Maintenance-Free (SMF) or AGM-type; recyclable; 20Ah standard / 40Ah extended; operational range: –40°C to +65°C
Control Box/Enclosure	Lockable, vandal-resistant aluminum housing; corrosion-resistant quarter-turn mechanism; NEMA 4X & IP66 compliant (IP67 for flood-prone areas)
Wire Harness & Clamps	Weatherproof harnesses and galvanized clamps for signal, battery, and solar panel mounting

Pole & Structure	GI or aluminum poles; 3”–4” diameter; 4–6 m height; optionally powder-coated or with decorative base cover
Power Supply	Total solid-state electronic circuitry; supports grid (120–240 VAC), solar, or hybrid configurations; 12V DC system voltage
Flashing Frequency	Adjustable between 30–40 flashes per minute
Operation Mode	24-hour continuous or 12-hour dusk-to-dawn operation
Control System	Integrated controller with remote configuration, power management, and diagnostics
Connectivity Features	Wireless sync via Bluetooth Low Energy (BLE); supports communication between up to 7 devices with a max range of 350 m
Network System	Supports 4G LTE (Cat-M1/NB2); multi-operator SIM; TCP/IP protocol; compatible with multiple global frequency bands
Activation (optional)	Push-button (mechanical or piezo-type) and/or passive pedestrian detection; ADA-compliant options available
Dimming & Accessibility (Optional)	Automatic dimming based on ambient light; audible alerts for visually impaired users
Certifications	IP65 (standard) / IP67 (flood-prone areas), CE, ISO 9001:2015, NEMA 4X

7.31.5. Construction Methods

- The flashing beacon system shall be installed in accordance with the approved Engineering drawings, manufacturer’s installation guidelines, and as directed by the Engineer.
- The signal blinker shall be mounted on a galvanized iron (GI) pole with a minimum diameter of 80 mm and a height ranging from 4 to 6 meters, as appropriate for site conditions and visibility requirements.
- The blinker unit shall be 200/300 mm in diameter, securely mounted near the top of the pole, and positioned to face oncoming traffic for maximum effectiveness.
- A solar panel, if used, shall be fixed on a bracket at the top of the pole, oriented to maximize solar exposure. The solar panel bracket shall be fabricated as shown in the detailed drawing to ensure structural integrity and optimal angle of inclination.
- The system's sealed maintenance-free (SMF) battery (for solar-powered beacon) shall be housed in a protective enclosure fixed to the pole at a reachable height for maintenance access. The enclosure shall be weather-resistant and lockable.
- All cabling (solar, battery, signal light) shall be routed through UV-resistant and weatherproof conduits and fastened securely along the pole. Appropriate surge protection shall be installed to safeguard against voltage spikes or lightning-induced damage.
- The pole shall be erected on a reinforced concrete foundation of 450 mm X 450 mm area and 800 mm depth, as shown in Figure 7.31-1. The foundation shall be constructed using Grade 25 concrete (or as specified), with adequate curing before pole erection.

- The base of the pole shall be fixed using anchor bolts or embedded sleeves, aligned vertically, and leveled before final tightening. All anchorage components must be be galvanized or corrosion-resistant.
- Installation shall include all incidental works such as excavation, backfilling, compaction, surface finishing around the foundation, and placement of necessary markings or reflective treatments as directed by the Engineer.

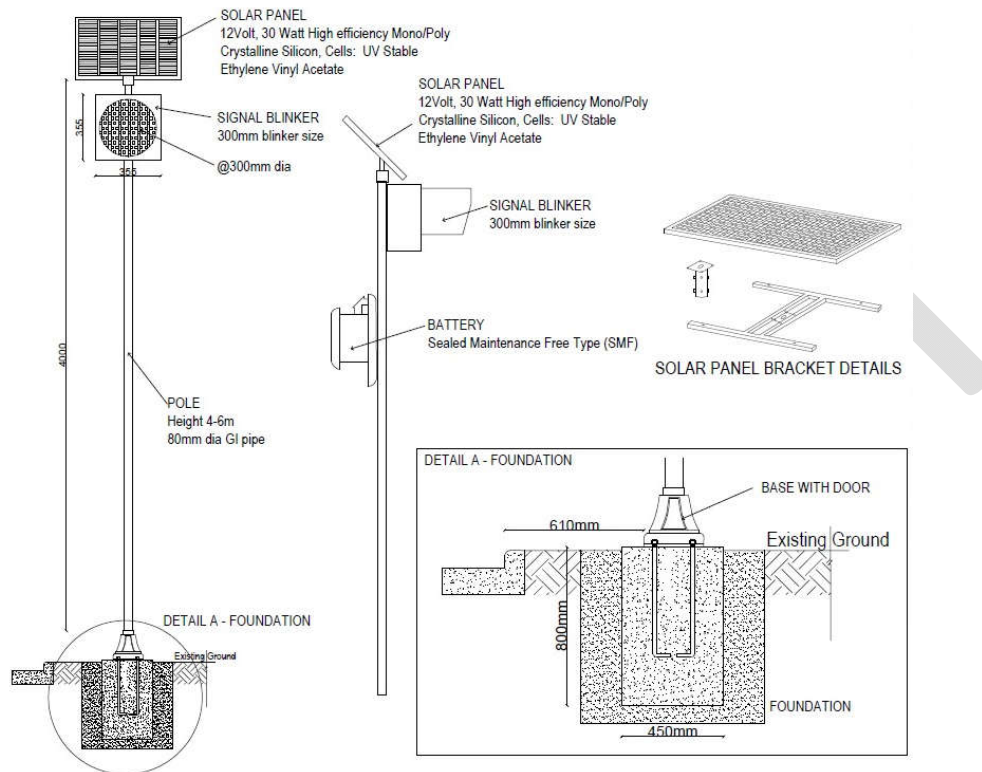


Figure 7.31-1: Typical example of flashing beacon installation.

7.31.6. Power and Autonomy

- **Solar-Powered Units:** Shall provide autonomous operation for a minimum of 7 consecutive days without sunlight.
- **Grid-Connected Units:** Shall operate on 120–240 VAC input with certified 12 VDC conversion.
- **Hybrid Systems:** May combine solar and grid inputs with automatic switching for backup operation.
- All systems shall include charge controllers, batteries (where applicable), and surge protection, ensuring functionality in adverse weather conditions such as monsoon, dust, and high humidity.

7.31.7. Measurement

The quantity of Flashing Beacons shall be measured in units of complete assemblies, separately categorized based on their power configuration: (a) solar-powered, and (b) hybrid (solar + grid) systems.

Measurement for flashing beacons shall be made based on the actual number of complete systems installed, tested, and accepted at designated locations, as shown on the Engineering drawings or as directed by the Engineer. Each measured unit shall include all components necessary for a fully functional and durable installation, including circular LED beacon unit(s), solar or hybrid power supply components, sealed battery units, control module, galvanized or powder-coated pole, mounting hardware, surge protection devices, and all structural fittings.

The scope shall also include the construction of pole foundations, anchoring systems, base plates, embedded sleeves (if used), and any civil works required for secure and permanent installation. Associated works such as trenching, cabling, conduit installation, protection enclosures, grounding, and surge protection shall be deemed included. No separate measurement shall be made for these individual elements.

7.31.8. Payment

Payment shall be made at the contract unit rate per complete Flashing Beacon system, and shall constitute full compensation for the supply, delivery, installation, integration, civil works, testing, commissioning, and all incidental works required to deliver a fully operational system in accordance with the Specification.

Pay items shall be:

Pay Items	Description	Unit
7.31	Solar-powered or Hybrid type Flashing Beacon system for regulatory or warning sign enhancement	
a	Solar-Powered	Number
b	Hybrid (Solar + grid) Systems	Number

7.32. Portable Reflectometers

7.32.1. General

This item covers the supply, calibration, operation, and maintenance of portable retro-reflectometers ("Reflectometers") for on-site measurement of nighttime and daytime luminance characteristics of (a) retro-reflective traffic signs and (b) thermoplastic road markings on the Roads and Highways

Department (RHD) network. The equipment shall support compliance verification with the luminance requirements set out in the corresponding sign and marking sections of this Specification.

7.32.2. Normative References

The Reflectometer(s) shall comply, as a minimum, with the most recent editions of the following standards (or their technical equivalents):

Application	Mandatory Standards*	Typical Geometry**
Traffic signs (RA)	EN 12899-1, ASTM E1709, ASTM E2540	Illumination $\beta = -4^\circ$ or $+5^\circ$; Observation $\alpha = 0.2^\circ, 0.5^\circ, 1^\circ$
Road markings (RL/Qd)	EN 1436, ASTM E1710	Illumination $\beta \approx 88.8^\circ$ (ASTM) / 1.24° (EN); Observation $\alpha = 1.05^\circ$ (ASTM) / 2.29° (EN)

Notes: RA: Coefficient of retro-reflection generally applies to retro reflective traffic signs; RL: Coefficient of retro-reflection under vehicle headlamp illumination generally applies to thermoplastic or painted road markings; Qd: the diffuse luminance coefficient, representing how visible markings are in daylight under diffuse lighting, measured only for road markings.

* Additional compliance with DIN 67520, MUTCD, and CUAP 01.06/04 shall be accepted.

** Alternative angle sets shall be acceptable if demonstrably equivalent per relevant standards.

7.32.3. Functional Requirements

a. Measurement Capability

- Nighttime coefficient of retro-reflection RA (traffic signs): 0 – 2000 $\text{cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$ minimum measurement range.
- Nighttime coefficient of retro-reflection RL (road markings): 0 – 4000 $\text{mcd} \cdot \text{m}^{-2} \cdot \text{lx}^{-1}$ minimum measurement range ($\text{mcd} \cdot \text{m}^{-2} \cdot \text{lx}^{-1}$: millicandela per lux per square meter).
- Daytime luminance coefficient under diffuse illumination Qd (road markings): 0 – 400 $\text{mcd} \cdot \text{m}^{-2} \cdot \text{lx}^{-1}$ minimum range.

b. Repeatability¹⁴

Instrument repeatability shall not exceed $\pm 2\%$ of the measured value for RL and Qd and $\pm 3\%$ for RA, verified by factory calibration certificates.

¹⁴ Repeatability refers to how consistent a device is when it measures the same thing multiple times under the same conditions. A highly repeatable instrument will give you nearly the same result every time denoting good performance of the device.

c. Measurement Time

A single test cycle (including internal averaging) shall not exceed 3 s for RA and 2 s for RL/Qd.

d. Data Acquisition & Traceability

- Integrated GNSS (GPS/WAAS or better) receiver providing position accuracy ≤ 3 m (CEP).
- Barcode / QR code reader for asset identification of signs and test panels.
- 5 MP color camera for capturing condition images linked to each record.
- Internal flash memory ≥ 1 GB, capable of storing $\geq 1\,000\,000$ measurements with metadata.

e. User Interface

- Back-lit color touchscreen display readable in direct sunlight.
- Menu available in English with option for Bangla character support.

f. Power & Autonomy

- Rechargeable Li-ion battery providing ≥ 8 h continuous operation at 25 °C.
- Supplied with 230 V ± 10 % 50 Hz charger and vehicle adapter (12–24 V DC).

g. Environmental Performance

- Operating temperature: -10 °C to $+50$ °C; storage: -20 °C to $+55$ °C.
- IP54 ingress protection or higher.

7.32.4. Standard Accessories (Each Device)

1. Factory calibration standard (traceable to ISO 17025).
2. Battery charger and spare battery pack.
3. USB-A host and USB-mini/USB-C data cables.
4. Rugged transport case (IP67).
5. Ergonomic short handle; extendable handle to 3 m (road-marking unit).
6. Mapping & analysis software (lifetime license), capable of exporting *.xls, *.csv, and *.kmz.
7. Portable thermal printer with consumables (road-marking unit).

7.32.5. Calibration and Verification

- Each Reflectometer shall be delivered with a manufacturer and calibration certificate issued within 30 days of shipment, clearly stating reference standards, uncertainty budgets, and traceability chains.
- A calibration reference panel shall be supplied for daily field checks.

- Re-calibration shall be performed at an ISO 17025-accredited laboratory at intervals ≤ 12 months or when drift exceeds $\pm 5\%$.

7.32.6. Software & Data Management

- The included software shall allow geospatial plotting, statistical analysis, trend graphs, and automatic PDF report generation keyed to RHD asset IDs.
- Data transfer shall be possible via USB and open JSON/CSV export for integration with the RHD Traffic Asset Management System (TAMS).

7.32.7. Field Use Guidelines and Acceptance Criteria

The following procedures shall be followed for the use of reflectometers during field testing of traffic signs and road markings to ensure consistency, accuracy, and traceable compliance with the Specification.

a. Measurement Method

1. Traffic Signs (RA Measurement):

- Each sign shall be measured at three locations: top-left, center, and bottom-right of the retro-reflective surface.
- The instrument shall be placed perpendicular to the surface as per the manufacturer's alignment guides.
- Measurements shall be taken under dry weather and during low ambient light conditions (e.g., dusk, dawn, or nighttime).
- A sign is considered compliant if all three readings exceed the minimum RA value specified in the respective sign section of this Specification.

2. Road Markings (RL and Qd Measurement):

- A minimum of five readings per 100 meters of continuous line shall be taken, distributed evenly across the segment.
- Each reading shall be made on a clean, dry surface under clear weather conditions.
- For Qd (daytime visibility), measurements shall be taken under diffuse daylight, avoiding shadows or direct sunlight.
- Data points shall be averaged for reporting purposes, unless any single reading falls below 80% of the minimum threshold, in which case reinspection or remedial action is required.

b. Instrument Setup and Data Handling

- Instruments shall be calibrated at the beginning of each testing day using the supplied reference panel.

- The GPS location, sign/markings ID (via barcode/QR), and photograph of the asset shall be recorded for each measurement.
- All measurement data shall be stored electronically and exported in CSV or KMZ format for central archiving and GIS mapping.
- Measurement files must include: device serial number, date/time, user ID, and calibration check status.

c. Acceptance and Rejection Criteria

- A sign or marking shall be accepted if all required readings meet or exceed the minimum retro-reflectivity values specified in the corresponding sections (e.g., per EN 12899-1 for signs, EN 1436 for markings).
- Any element with more than 20% of readings falling below the specified threshold shall be rejected and scheduled for replacement or reapplication.
- Results shall be verified by the Engineer. Disputed values may be cross-checked using the RHD's reference reflectometer.

d. Reporting

- Field reports shall include:
 - Location maps with measurement points (from GPS)
 - Photos of each asset
 - Tabulated results with pass/fail status
 - Summary of calibration status and operator details
- Reports shall be submitted electronically and archived in the RHD Traffic Asset Management System (TAMS).

7.32.8. Training, Documentation & Warranty

- Training: Minimum 2 × 1-day hands-on sessions for RHD inspectors/representatives covering operation, calibration, data handling, and maintenance.
- Documentation: User manuals (English) and quick-start guides (Bangla) shall be provided in printed and PDF form.
- Warranty: Minimum 24 months parts and labor; 10-year spare-part availability commitment.

7.32.9. Inspection & Acceptance

- Factory Acceptance Test (FAT) certificates shall be reviewed prior to shipment.
- Site Acceptance Test (SAT) shall comprise (i) repeatability checks on certified panels, (ii) comparison with RHD reference unit, and (iii) demonstration of data export. Acceptance criteria: deviation $\leq \pm 5\%$ of reference values.

7.32.10. Measurement

Measurement shall be made for the actual number of reflectometer devices supplied, tested, and accepted by the Engineer, categorized into two functional types:

- Type A: Reflectometer for Traffic Signs (measuring retro-reflectivity RA)
- Type B: Reflectometer for Road Markings (measuring retro-reflectivity RL and luminance coefficient Qd)

Each unit shall be measured individually, provided it includes all required accessories, calibration tools, software, documentation, and is delivered in full compliance with the technical specifications outlined in this section.

Partial deliveries or units failing to meet acceptance tests (FAT/SAT) shall not be measured for payment. Separate records shall be maintained for each type to ensure traceability of delivered equipment by device type and serial number.

7.32.11. Payment

Payment shall constitute full compensation for the procurement, factory calibration, delivery, testing, acceptance, accessories, training, documentation, software, warranty, and all incidental costs necessary to place the equipment in satisfactory operating condition, complete and accepted by the Engineer. No separate payment shall be made for transportation, duties, or integration of data with RHD's systems. Payment shall only be made for units passing both Factory Acceptance Tests (FAT) and Site Acceptance Tests (SAT).

Pay Items shall be:

Pay Items	Description	Unit
7.32.1	Portable Reflectometer for Traffic Signs (RA Measurement): Portable, battery-operated retro-reflectometer with measurement geometry compliant with EN 12899-1, ASTM E1709, and ASTM E2540 (illumination angle β : -4° or $+5^\circ$, observation angle α : 0.2° , 0.5° , 1°); including shoulder strap, universal battery charger (100 V–240 V, 50–60 Hz), calibration standard (traceable to ISO 17025), GNSS-enabled mapping and data analysis software, USB cable for data transfer, Bluetooth module, integrated barcode reader and onboard camera, and complete documentation.	Number
7.32.2	Portable Reflectometer for Road Markings (RL and Qd Measurement): Portable, wheeled, battery-operated retro-reflectometer compliant with EN 1436 and ASTM E1710, capable of measuring nighttime retro-reflectivity (RL) and daytime visibility (Qd); including calibration standard (ISO 17025 traceable), universal battery charger (100 V–240 V, 50–60 Hz), ergonomic short and extendable handle (up to 3 m), integrated GPS, thermal printer with consumables, onboard display, data logging system,	Number

	data export software, and carrying case with wheels, along with complete documentation.	

Road Safety Technical Specification: Part II

The deployment of Intelligent Transport Systems (ITS) in Bangladesh is guided by the evolving Bangladesh National ITS Master Plan for Roads and Highways Department (RHD). This plan seeks to contextualize international ITS frameworks for local applications, based on the country's current infrastructure maturity and deployable technologies. According to the 2017 UNESCAP report, six fundamental ITS service categories dominate the Asia-Pacific region:

1. Advanced Traffic Management System (ATMS)
2. Electronic Toll Collection System (ETCS)
3. Advanced Traveler Information System (ATIS)
4. Advanced Public Transportation System (APTS)
5. Emergency Management System (EMS)
6. Commercial Vehicle Operations (CVO)

Among the six ITS service categories, Advanced Traffic Management System (ATMS) stands out as the most practical, widely deployed in the Asia-Pacific region, and the most viable for implementation by the Roads and Highways Department (RHD) in the current context. ATMS serves as a core component of an Intelligent Transport System (ITS), aimed at optimizing traffic flow, enhancing road safety, and improving overall transport efficiency. It leverages a combination of sensors, communication networks, software, and control devices to achieve these goals. Key ATMS functions identified for deployment in Bangladesh include the Automated Traffic Counter and Classifier (ATCC), Security Surveillance (SS), Automated Speed Enforcement System (ASES), Variable Message Signs (VMS), Video Incident Detection Systems (VIDS), and Road Weather/Environment Information Systems (RWIS). These components work in tandem through a combination of sensors, communication infrastructure, software platforms, and control devices, offering a scalable and effective framework for advancing road safety and traffic management in Bangladesh.

Looking into the past development of ITS infrastructure and services, user-oriented services such as ATIS and APTS gained attention only after a minimum level of automated traffic management was achieved. Building on the success of mid-level ITS services, Advanced Public Transportation Systems (APTS), Advanced Traveler Information Systems (ATIS), and other advanced technologies can be considered for future deployment to further enhance traffic efficiency and road safety in Bangladesh.

Customized ITS Service Areas for Bangladesh

The draft Bangladesh National ITS Master Plan for RHD provides a generic overview of ITS services, sub-services, physical components, logical architecture, and data flow diagrams (DFDs) for various service areas. These show how ITS elements are functionally distributed across **Road segments**, **Traffic management centers**, **traveler interfaces**, and **cooperating entities** (e.g., Police, Hospitals, Meteorological Department).

While the Bangladesh National ITS Master Plan for RHD outlines a range of service areas, not all are structured. Based on analysis and contextual feasibility, the following customized service areas and their associated ITS components are considered in this Specification for implementation in Bangladesh:

Table: ITS Service Areas and Applicable Components for Road Safety and Operations in Bangladesh

Service Area	Sub-service Areas	Applicable ITS Components
Advanced Traffic Management System (ATMS)	- Real-time traffic monitoring service - Basic transport information dissemination - Traffic/emergency/special road info (flood, congestion, blockage,	ATCC, VIDS, ASES-SS, RWIS, VMS, ASES, Traffic Management Centers (TMC), Mobile Apps, Web Portals

	accident) - Transport information management - Incident detection - Speed violation detection and speed limit enforcement - Security surveillance - Illegal stopping/parking enforcement - Road weather monitoring (e.g., fog, storm, heavy rain) - Expressway traffic flow control - Exclusive Lane guidance - Automated traffic counting and classification	
Emergency Management Service (EMS)	- Emergency detection and response - Emergency vehicle operation support - Emergency medical support	VIDS, VMS, Emergency Communication Systems (Emergency Call Boxes, Mobile Communication System), Traffic Management Centers (TMC)/Call Center, Web portal
Electronic Toll Collection (ETCS)	- Electronic toll payment - Congestion tolls - Parking fee collection - Public transport fare collection	RFID Readers, DSRC Units, ATCC, VMS, Toll Management Centers, Mobile Apps, Web portal
Commercial Vehicle Operations (CVO)	- Overweight vehicle enforcement - Load restriction - Dangerous goods and overloaded freight management	RFID Readers, DSRC Units, VMS, Weighbridges, ATCC, ALCS Management Centers

From Function to Specification

Based on the customized ITS service areas, sub-service functions, and deployable technologies in the context of Bangladesh, this Technical Specification includes the following components:

- Video Incident Detection System (VIDS)
- Automated Speed Enforcement System (ASES) integrated with Security Surveillance (SS)
- Road Weather/Environment Information System (RWIS)
- Emergency management System (EMS)

- Electronic Toll Collection System (ETCS)
- Overload Control System
- Variable Message Signs (VMS)
- Automated Traffic Counter and Classifier (ATCC)
- Traffic Management Center (TMC)
- Optical Fiber Communication (OFC) Network

Each component included in this document is detailed in terms of its functional role within the broader ITS architecture, the physical components required for deployment (such as sensors, controllers, and cameras), performance requirements based on relevant operational standards, and clearly defined measurement and payment items to ensure accurate budgeting and accountability for contractors. This structured approach ensures alignment with international ITS best practices while remaining responsive to the practical and scalable deployment needs of Bangladesh.

7.33. Video Incident Detection Systems (VIDS)

The Video Incident Detection System (VIDS) is a key element of RHD's Intelligent Transport System (ITS), aligned with the Bangladesh National ITS Master Plan to suit local infrastructure and deployment needs. Powered by artificial intelligence (AI), machine learning (ML), and computer vision techniques, the VIDS platform automatically detects and categorizes a wide range of traffic incidents, including stopped vehicles, collisions, jaywalking, wrong-way driving, and fire/smoke hazards, using high-resolution video analytics. The system is designed to provide timely alerts and detailed event metadata to the central/regional Traffic Management Centers (TMCs), thereby improving situational awareness and operational response.

This specification outlines the complete technical and operational framework for deploying VIDS, including system functionality, detection capabilities, hardware and software architecture, and integration with TMCs. It also covers edge and cloud processing requirements, along with provisions for data management, security, resilience, accuracy, and interoperability. The VIDS platform is

designed to enhance road safety, optimize traffic flow, and support data-driven management of RHD highways.

7.33.1. Generic Requirements

The primary objective of VIDS is to enable continuous, automated detection of critical or abnormal roadway incidents at key locations, junctions, or traffic entities, as determined by the Engineer, for real-time detection (with a minimum acceptable detection accuracy), verification, and response.

Typical VIDS deployment locations include, but are not limited to:

- Critical junctions and intersections where signal violations, wrong-way entries, or vehicle-pedestrian conflicts are common.
- Tunnel entrances/exits, flyovers, bridges, and underpasses, where traffic conditions can change rapidly.
- Toll plaza approaches and egress zones, where vehicle queuing, sudden stops, and congestion buildup are frequent.
- Pedestrian-heavy areas such as market zones, bus terminals, school zones, and crossings susceptible to jaywalking or crowd-related disruptions.
- Weaving areas and merge/diverge zones where abrupt lane changes and deceleration increase crash risk.
- Accident-prone segments, blackspots, and crash clusters identified through historical data or road safety audits.

All VIDS locations shall be selected in coordination with RHD's Road Design and Safety Circle and shall be integrated with the nearest Traffic Management Center (TMC) for efficient processing, notifying, and archiving.

7.33.2. Technical and Functional Requirements

7.33.2.1. Definition of Traffic Incidents for VIDS

A traffic incident, for the purpose of the Video Incident Detection System (VIDS) under the Intelligent Transport System (ITS) framework of the Roads and Highways Department (RHD) of Bangladesh, can be defined as:

“An unplanned, non-recurring event occurring on or near the roadway that leads to a reduction in roadway capacity, abnormal traffic flow, or elevated safety risks to road users. Such incidents may involve physical obstructions or behavioral disruptions and include, but are not limited to, vehicle collisions, stalled or slow-moving vehicles, unauthorized pedestrian crossings (jaywalking or chicken

runs), fire or smoke on the roadway, fallen objects, erratic driving behavior, and spontaneous traffic congestion.”¹⁵

Planned roadway activities, such as routine maintenance or construction projects, are explicitly excluded from this definition. Likewise, large-scale emergencies, such as natural disasters or terrorist attacks, while they may affect traffic flow, fall outside the detection scope of VIDS due to their broader emergency management implications and multi-domain impact beyond the roadway environment. While VIDS is a critical subsystem for the automated detection of such incidents, it does not perform functions such as security surveillance, speed enforcement, or environmental hazard detection (e.g., fog, rain). These functions fall under other ITS components deployed by RHD, including:

- Security Surveillance Systems (SS)
- Automated Speed Enforcement Systems (ASES)
- Road Weather Information Systems (RWIS)

Integration of VIDS with these complementary ITS subsystems is addressed in other sections of this specification.

7.33.2.2. Incident Management and Classification Framework

The Video Incident Detection System (VIDS) shall incorporate a structured, interoperable framework for incident reporting and classification, in alignment with the National Incident Management System (NIMS) and its associated Incident Command System (ICS), as established by the U.S. Department of Homeland Security and described in Chapter 6I of the Manual on Uniform Traffic Control Devices (MUTCD).

According to NIMS and MUTCD guidelines, traffic incidents shall be classified into three categories based on their **expected duration** and operational impact:

- **Minor Incident** (Duration < 30 minutes)
Typically does not require extensive scene management or lane closure.
Examples: Disabled vehicles, minor property-damage crashes, small road debris

¹⁵ This definition is adapted from *Gordon (2016)* and harmonized with the incident management principles of the *National Incident Management System (NIMS)* and *Incident Command System (ICS)*, which establish a standardized, scalable framework for incident response across all levels of government and agencies (*FEMA, 2017*).

- **Intermediate Incident** (Duration 30 minutes to 2 hours)
Requires temporary traffic control and moderate response coordination.
Examples: Multi-vehicle crashes, injury crashes, overturned light vehicles
- **Major Incident** (Duration > 2 hours)
Causes full or partial closure and requires a coordinated multi-agency response.
Examples: Fatal crashes, hazardous materials spills, truck rollovers, infrastructure damage, fire/smoke

The duration classification reflects not only the time to clear the incident physically but also the time required to restore safe and normal traffic operations (*National Incident Management System, FEMA; MUTCD Chapter 6I – Traffic Incident Management*).

7.33.2.3. Classification of VIDS-detectable Incidents

The Roads and Highways Department (RHD) has defined a set of traffic incidents to be automatically detected, reported, and classified by the Video Incident Detection System (VIDS) deployed under its Intelligent Transport System (ITS) framework. These incident types represent common and critical non-recurring roadway events that impact traffic safety and flow. The VIDS shall detect the defined events in real time and classify them according to the duration-based categories, Minor, Intermediate, and Major, outlined in the National Incident Management System (NIMS) and MUTCD Chapter 6I, as summarized in Table 7.33-1.

Table 7.33-1: VIDS incident types and NIMS classification

VIDS Incident Type	NIMS Classification	Remarks
Disabled vehicle or illegal stop	Minor	Typically cleared within 30 minutes
Jaywalking / Chicken run	Minor	No vehicle impact unless a collision occurs
Falling or dropped object	Minor / Intermediate	Duration varies with object type and removal time
Vehicle stopped in active lane	Intermediate	May require traffic control support
Queue formation and congestion buildup	Intermediate	Requires ongoing monitoring, may escalate
Minor collision (no injury)	Minor /	Based on damage and blockage

Movement or gathering of people on the roadway/ Road block	Minor / Intermediate	May create a pedestrian hazard or delay; risk depends on location/context
Speed drop / sudden deceleration	Intermediate	Could indicate an incident or hazard ahead; requires system-generated alert
Environmental hazard (fog/flood/storm detection) ¹⁶	Intermediate / Major	Triggers visibility-related alerts; risk level depends on severity/location
Multi-vehicle crash or injury crash	Intermediate/ Major	May require emergency service response
Wrong-direction vehicle movement (reverse or across	Major	High risk, requires immediate alert and intervention
Fire or smoke from a vehicle or roadside	Major	Life-threatening; full emergency response required
Fatal crash or hazardous spill	Major	Critical incident with multi-agency coordination
Overtaken truck or large commercial vehicle	Major	Road blockage and safety risk

Note: Adapted from *National Incident Management System* (3rd ed., p. XX), by Federal Emergency Management Agency, 2017, U.S. Department of Homeland Security

7.33.2.4. Incident Command System (ICS) Integration

The Video Incident Detection System (VIDS) shall support the core principles of the Incident Command System (ICS), which include standardized communication protocols, unified multi-agency command, real-time incident documentation, and operational coordination. VIDS shall be fully interoperable with Traffic Management Centers (TMCs) and shall generate structured incident data to support all relevant stages of the incident management lifecycle, from detection to recovery and termination.

By design, VIDS enhances the capability of TMCs to manage incidents in accordance with ICS-based workflows. It provides the foundational data layer for detection, classification, communication, situational assessment, and archival, enabling more effective coordination between emergency services (e.g., traffic police, fire services, emergency medical services), highway authorities, and other ITS subsystems.

VIDS shall enable the following core functionalities:

¹⁶ This incident, though tabulated for VIDS detectable incidents, is objectively detected through the Road Weather Information System (RWIS)

- **Automatic alerting** to TMCs and emergency response units upon incident detection
- **Generation of structured incident records**, including incident type, severity, location, time, lane occupancy, and estimated duration
- **Real-time situational awareness** through continuous video feeds and incident updates for use by the designated **Incident Commander**
- **Support for Unified Command**, allowing multiple stakeholders to access incident status, share common objectives, and coordinate response efforts
- **Plain-language communication**- ensuring incident data is free from radio codes or agency-specific jargon, facilitating cross-agency clarity
- **Inter-agency compatibility** of all alert messages, logs, and archived data formats for use in audits, training, and policy review

Table 7.33-2 below summarizes how VIDS supports each stage of incident management.

Table 7.33-2: VIDS-Supported Incident Management Functions and Stages (adapted from (Gordon, R., 2015)).

VIDS-Supported Incident Management Function	Detection & Verification	Response	Clearance	Recovery
Detect an incident and identify its properties (e.g., lane blockage, location, direction)	√			
Classify incident into type and severity (Minor / Intermediate / Major – as per NIMS classification)	√			
Notify responding agencies of incident metadata (location, type, estimated duration, severity)	√	√		
Enable integrated alert dissemination to motorists via VMS, mobile alerts, and web portal (when interfaced)		√	√	√
Provide traffic conditions and/or route guidance to responding agencies		√	√	√
Archive incident video and data for post-event review, analysis, planning, and auditing (incident logs, timestamps, evidence snapshots)			√	√
Enable or support confirmation of incident clearance through visual verification			√	√
Close the incident record with the final log entry and mark it for archival				√

7.33.2.5. Role of CCTV in Incident Detection and Location Prioritization

Closed-Circuit Television (CCTV) surveillance has proven to be one of the most effective tools for incident detection and verification in Intelligent Transport Systems (ITS). Compared to traditional methods such as emergency calls or manual patrols, CCTV enables faster detection of incidents by

continuously monitoring roadway conditions in real time. It not only detects events but also verifies incident characteristics on an evidence basis, allowing Traffic Management Centers (TMCs) to assess severity and dispatch the appropriate response quickly. This combination of detection and visual verification minimizes response time and improves coordination with emergency services.

The relationship between CCTV deployment coverage, system benefit, and installation cost is illustrated in Figure 7.33-1 below. The graph demonstrates that:

- The marginal benefit of CCTV increases rapidly in early deployment stages, especially in high-demand corridors (Curve A).
- Beyond 70–80% coverage, the benefit curve flattens, indicating diminishing returns.
- Meanwhile, the cost curve (C) increases exponentially due to overlapping coverage and infrastructure intensification.
- Therefore, net benefit is maximized when coverage is strategically targeted rather than uniformly distributed.

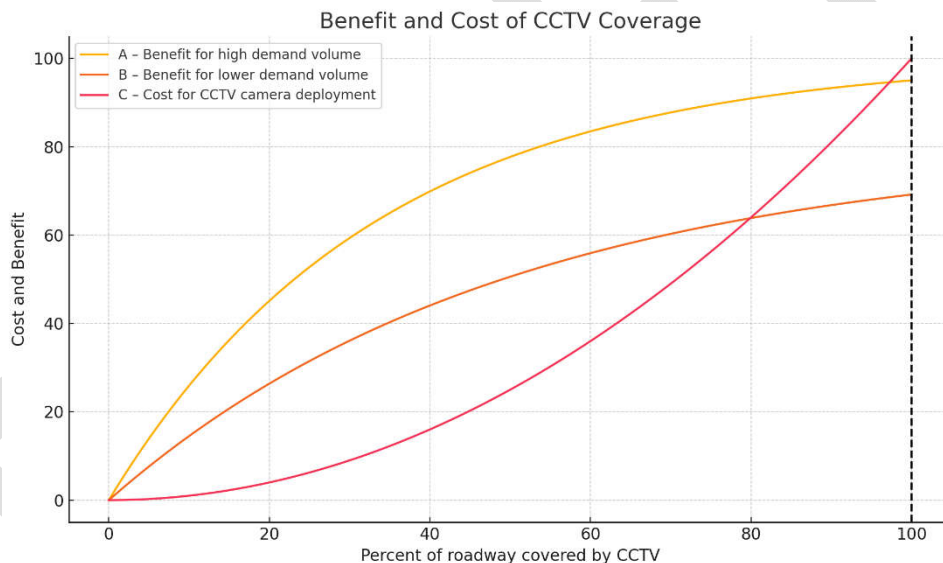


Fig. 7.33-1: Benefit and Cost of CCTV Coverage based on Percent of Roadway Covered

Source: Adapted from *Region 4 ATMS Local Evaluation Report*, Dunn Engineering Associates, 2005.

Based on the cost-benefit analysis illustrated in Figure 7.33-1, full CCTV coverage across all roadway segments is not economically optimal due to diminishing returns at higher coverage levels and escalating infrastructure costs. Therefore, the Roads and Highways Department (RHD) shall adopt a targeted deployment strategy that prioritizes surveillance where it delivers the highest benefit per unit cost.

CCTV coverage shall be focused on roadway segments with elevated traffic volumes, high incident probability, or strategic importance. Priority locations include:

- High-incident areas such as intersections, interchanges, and accident blackspots
- Traffic bottlenecks, including freeway ramps and weaving zones
- Critical infrastructure such as toll plazas, tunnels, bridges, and roadside facilities
- High-volume corridors where peak-hour traffic operates at Level of Service (LOS) C or worse

This approach ensures cost-efficient deployment, while preserving high standards for real-time incident detection, traffic monitoring, and coordinated response.

7.33.2.6. CCTV Camera Optical and Placement Requirements for VIDS

To ensure consistent incident detection performance across varying environmental and lighting conditions, all CCTV cameras used in the Video Incident Detection System (VIDS) shall conform to the following technical parameters based on IEC EN 62676-4:2015 (DORI model) and international ITS deployment practices:

DORI-Based Optical Performance

DORI (Detection, Observation, Recognition, Identification) is an industry standard that defines the level of detail in PPM (Pixel Per Meter) required for a visible surveillance camera to obtain Detection, Observation, Recognition, Identification. The camera's optical system shall support surveillance and analytics at the following minimum pixel density levels, defined in Pixels Per Meter (PPM) at the target area:

Table 7.33-3: DORI-based image quality requirements for CCTV cameras in VIDS

DORI Level	Purpose	Required PPM	Function in VIDS
Detection	Identify object presence	≥ 25 PPM	Basic motion/stopped vehicle detection
Observation	Detect shape, direction, and activity	≥ 62 PPM	Wrong-way driving, queue formation, object drop
Recognition	Match a known vehicle or person	≥ 125 PPM	Confirm returning violator or suspect behavior
Identification	Determine identity beyond doubt	≥ 250 PPM	License plate, facial, or branding verification

These levels must be achieved under daylight and night illumination at the intended coverage range of the camera (typically 100–200 meters) [IEC EN 62676-4:2015].

Resolution and Focal Length

The required pixel density shall be verified through calculations based on camera resolution, field of view, distance to target, and mounting height. However,

- Cameras shall have a minimum resolution of 4 MP (2688×1520) for general-purpose incident detection, and 5 MP or higher for applications requiring object recognition or license plate capture [IEC EN 62676-4:2015].
- Lens focal length shall be selected based on the required DORI range:
 - 2.8–4 mm for wide-angle FOV in short-range urban settings
 - 8–50 mm (or motorized zoom) for highways and narrow corridor coverage [FHWA, 2009]

Field of View and Target Coverage

- Cameras shall be configured to provide a horizontal Field of View (FOV) suitable for the number of lanes to be covered (typically 2–3 lanes).
- The FOV width at the detection plane shall correspond to the required PPM level and resolution. However, the effective detection and surveillance range of each camera shall be not less than 100 meters and not more than 200 meters to ensure optimal object detection and video analytics performance.
- The horizontal angle shall be selected such that the effective detection zone maintains high sharpness at the image center.
- Mounting height, target height, and viewing angle shall be coordinated to eliminate parallax errors and obstruction by large vehicles.

Mounting and Environmental Suitability

- All cameras shall be installed at a height of 8–12 meters, ensuring clear line-of-sight and minimizing obstruction and occlusion problems during the detection process.
- In environmentally challenging areas, cameras shall be equipped with:
 - Infrared (IR) or Near-Infrared (NIR) illumination for low-light performance
 - Wide Dynamic Range (WDR) or High Dynamic Range (HDR) sensors to manage glare, shadows, and varied lighting

Camera Overlap Zones

- Adjacent cameras shall be installed with an overlap of 10% to 15% of their horizontal field of view.
- Overlap shall be provided to eliminate blind spots, support vehicle tracking across zones, and enhance incident confirmation.

- The overlap shall be verified during system commissioning through calibration and test viewing angles [NCHRP, 2014].

An example overview to select FOV based on DORI is given in Figure 7.33-2. The camera height, distance, focal length, resolution, and related parameters for the intended purposes of VIDS shall be analyzed using such online available toolkits (example link: <https://www.jvsg.com/calculators/cctv-lens-calculator/>) before finalizing the selection of and placement of the specific camera models.

DRAFT

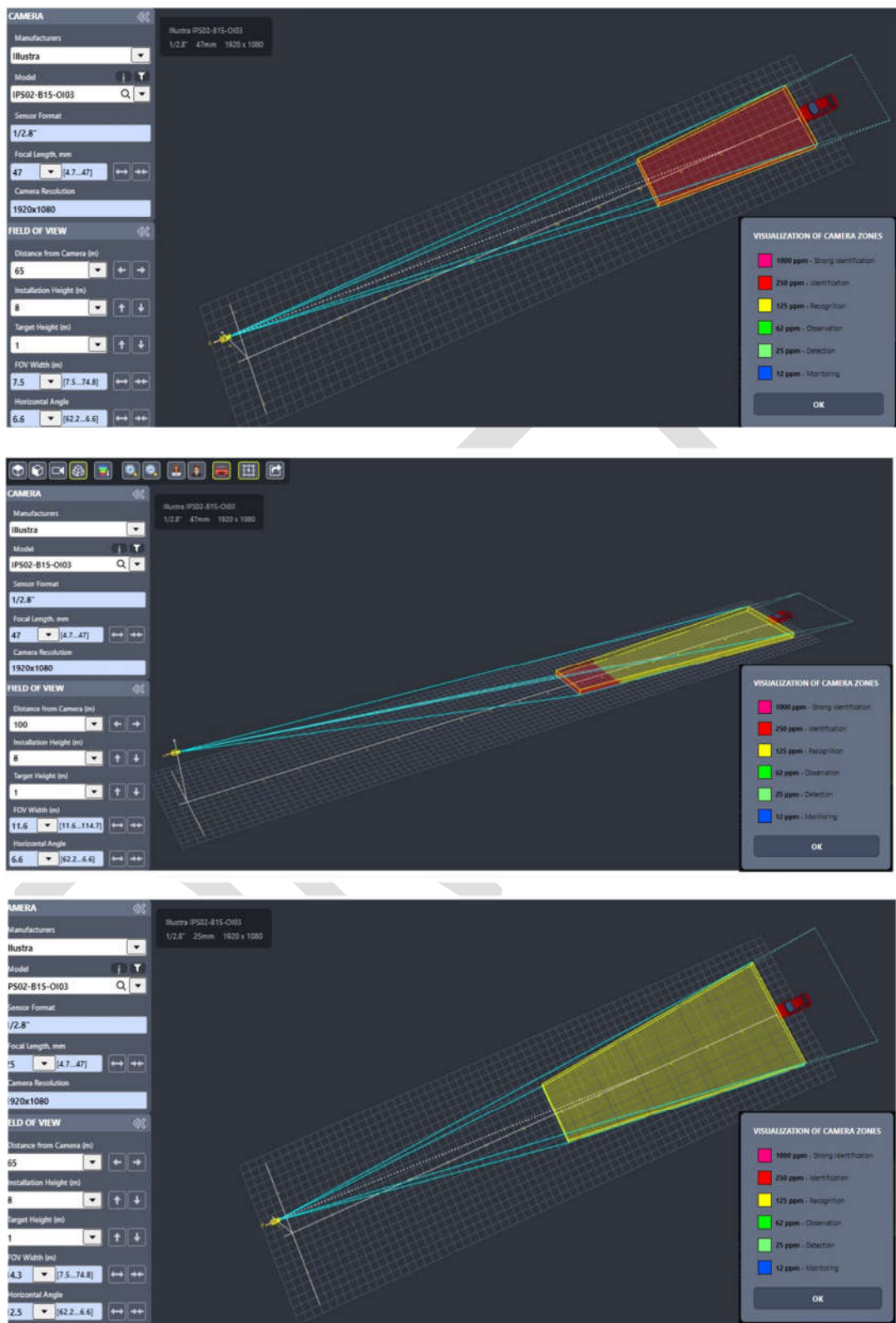


Figure 7.33-2: DORI-based identification of FOV and

7.33.3. Hardware Requirements

The Video Incident Detection System (VIDS) shall be supported by a robust, scalable, and resilient hardware infrastructure designed for 24/7 real-time monitoring, automated incident detection, edge-based video analytics, alert generation, and data communication across strategic highway corridors under the Roads and Highways Department (RHD) of Bangladesh. The system must ensure high availability, operational continuity, and resistance to environmental extremes, electrical surges, and vandalism typical of roadside deployments.

The following sub-components have been selected to meet the demanding environmental and operational conditions of national highways while ensuring seamless system integration, high performance, and long-term reliability.

1. **Local (Video Image) Processing Unit (LPU)** - On-site edge analytics module for multi-lane incident detection using AI and deep learning.
2. **Video Surveillance Camera with IR Filter and Sunshield and Self-cleaning/ maintenance assist system** - High-resolution, weatherproof cameras for 24/7 video feed and analytics support with automated lens cleaning or hydrophobic coatings for environments prone to dust, fog, or pollution.
3. **Pole/Gantry-Mounted Flashing Warning Lights** - High-intensity LED beacons for alerting motorists of active incidents.
4. **High-Performance Industrial Network Switch** - Managed Ethernet switches with PoE and redundancy for stable field-to-TMC communication.
5. **Electronic Equipment Cabinets** - Outdoor-rated enclosures to house VIPUs, UPS, network devices, and associated hardware.
6. **Uninterrupted Power Supply (UPS)** - A Backup power system ensuring continuous operation for at least 4 hours during outages.
7. **Solar Lighting Units** - Energy-efficient illumination for remote sites or supplemental visibility at night.
8. **Hooter Alarms and Signal Systems** - Audible alerts triggered during high-risk incidents (e.g., fire, wrong-way driving).
9. **Power Connection Arrangement** - Grid-based or off-grid structured power delivery system with circuit protection and ATS integration.
10. **OFC / ISP Communication Arrangement** - High-speed fiber or cellular backhaul infrastructure for real-time data exchange with TMC.
11. **Anti-Theft Protection System** - Physical deterrents and intrusion monitoring to prevent unauthorized access or equipment theft.
12. **Redundant Power Switching Module** - Automatic source switching between grid, UPS, and solar inputs for uninterrupted functionality.

13. **Motion Detection Camera for Intrusion Alarm** - Surveillance to detect unauthorized activity around sensitive field assets.
14. **Lightning Arrestor** - Surge diversion device to prevent equipment damage from lightning strikes.
15. **Surge Protection and Grounding System** - Integrated SPD and grounding network to shield equipment from electrical surges and ensure safety.

7.33.3.1. Local Video Image Processing Unit (VIPU)

The Local Video Image Processing Unit shall serve as the intelligent core of the VIDS system, performing high-speed, on-site video analytics for incident detection, traffic monitoring, and real-time alert generation. It shall operate independently or in coordination with the TMC and support continuous processing from multiple high-resolution camera feeds. The VIPU shall include integrated AI acceleration to support real-time deep learning inference for edge-based detection of multiple incident types.

Technical Specifications:

Description	Value / Requirement
Processor	6-12 core NVIDIA Arm® Cortex A78 v8. (e.g., NVIDIA Carmel) or equivalent high-performance embedded CPU with > 2.0 GHz frequency
GPU / Edge AI Accelerator	Integrated NVIDIA Ampere GPU with ≥ 1024 CUDA cores and 32 Tensor Cores, ≥ 100 TOPS AI performance at > 1GHz
AI Framework Support	TensorRT, CUDA, cuDNN, OpenCV, ONNX Runtime, PyTorch
Video Channels	Support for processing at least four (04) simultaneous 1080p video feeds
AI Functionality	Multi-lane vehicle detection, wrong-way movement, stopped vehicle, queue buildup, pedestrian detection, smoke/fog analysis
RAM	Minimum 16 GB LPDDR5
Storage	256 GB eMMC or NVMe SSD support up to 1TB, expandable (with edge buffer support for offline storage)
Network Interface	Dual Gigabit Ethernet with VLAN support; RJ45 ports; support for PoE
Input Ports	CSI or GMSL inputs (supporting high-def camera integration)
Output Ports	HDMI for local display, optional serial or GPIO for alarm signaling
OS and Software	Ubuntu 20.04 LTS or equivalent Linux-based distribution with preloaded VIDS software framework and remote OTA update capability
Communication Protocols	TCP/IP, HTTP(S), FTP, SNMP, MQTT, ONVIF, RTSP
Alarm Handling	Real-time alert generation; support for programmable rules and triggers
Mounting	DIN rail, shelf, or inside electronic cabinet

Power Supply	12–24V DC input, ≤ 60W power consumption (fanless or passive cooling preferred)
Operating Temperature	–20°C to +65°C
Ingress Protection	IP30 or higher (indoor protected cabinet); protected from dust and vibration
Security Features	Secure boot, firmware encryption, hardware-level watchdog
Compliance	CE, RoHS, FCC, EN55032/35 Class A, IEC 61000-4

7.33.3.2. Video Camera(s) with IR Filter, Enclosure, and Sunshield

The VIDS surveillance camera shall be used for 24/7 video capture in all lighting and environmental conditions. It shall support advanced video analytics for detecting abnormal traffic behavior, including stopped vehicles, jaywalking, falling objects, queue formation, and speed anomalies. The camera shall be suitable for outdoor mounting on poles or gantries and shall integrate seamlessly with the VIPU.

Technical Specifications:

Description	Value / Range
Image Sensor	1/2.8" Progressive Scan CMOS
Resolution	Minimum 4 MP (2688 × 1520)
Shutter Speed	1/3 s to 1/100,000 s (suitable for moving objects)
Minimum Illumination	0.01 Lux @ F1.2 (color); 0 Lux with IR
IR Illumination	Integrated IR LEDs with a minimum 50 m range
Lens	Motorized varifocal, 2.8–16 mm (optional 8–32 mm for highway)
Lens Mount	M12 or CS-mount
Wide Dynamic Range (WDR)	≥ 120 dB
Frame Rate	30 fps at full resolution, > 50 fps for highways
Compression Format	H.265 / H.264 / MJPEG
Video Analytics Support	Compatible with VIPU detection zones; edge-based basic analytics enabled
Communication Interface	RJ45 10/100 Ethernet; ONVIF Profile S/G compliant
Operating Temperature	–30°C to +60°C
Housing Protection	IP67-rated weatherproof, IK10 vandal-resistant metal enclosure
Sunshield	Removable or integrated, anti-glare design
Power Supply	PoE (IEEE 802.3af/at) or 12V DC ±10%
Power Consumption	Max 15 W with IR ON
Certifications	CE, FCC, RoHS, ONVIF, UL

For locations subject to dust, fog, bird activity, or salt spray, the camera shall optionally include a built-in lens cleaning system. This may consist of a wiper/nozzle-based solution or an advanced hydrophobic

lens coating to ensure continuous visibility and maintain image clarity. Cleaning cycles shall be remotely configurable from the Traffic Management Center (TMC).

Self-Cleaning / Maintenance-Assist System (Optional but Recommended)

Feature	Specification
Cleaning Type	Lens-integrated nozzle spray system, wiper-based mechanism, or hydrophobic coating
Control Trigger	Manual via TMC command or scheduled periodic cleaning via timer/controller
Water Tank / Fluid Type	Non-abrasive lens cleaning solution (min. 1 liter capacity if tank-based)
Integration	Integrated with camera housing or mount arm; compatible with camera control unit
Maintenance Interval	Minimum 100 cleaning cycles without refill (tank-based); continuous (coating)
Operating Temperature	-20°C to +60°C; UV- and corrosion-resistant
Optional Add-On	Automatic rain/fog sensing trigger

7.33.3.3. Pole/Gantry-Mounted Flashing Warning Lights

The flashing warning lights shall provide visible alerts to motorists in the event of an incident detected by the VIDS. These lights are crucial for warning approaching vehicles of hazardous situations like wrong-way movement, stopped vehicles, fire/smoke, or congestion. They shall be integrated with the VIDS system and activated automatically via incident detection from the VIPU.

Technical Specifications:

Description	Value / Range
Light Type	High-intensity LED beacon
Illumination Color	Amber (preferred for highway safety) or Red (in special zones)
Visibility Range	Minimum 500 meters in clear atmospheric conditions
Flash Rate	1–2 Hz (60–120 flashes per minute)
Light Intensity	≥ 200 cd (candela), adjustable
Beam Angle	120° horizontal, 60° vertical
Mounting Compatibility	Suitable for installation on 3"–4" diameter poles or gantry arms
Housing Protection	IP66 or higher, UV-stabilized polycarbonate lens with aluminum base
Operating Temperature	-40°C to +60°C
Control Interface	Dry contact input or TCP/IP signal from VIPU or TMC systems
Synchronization	Supports multiple lights flashing in unison for wide-area alerts
Power Supply	12V or 24V DC; solar-capable or UPS integrated
Power Consumption	≤ 15W per unit
Compliance	MUTCD Chapter 4K.02 and EN 12352 (where applicable)
Expected Lifespan	≥ 50,000 hours (LED lifetime)

7.33.3.4. High-Performance Industrial Network Switch

The Industrial Network Switch shall serve as a robust and reliable data communication backbone for the VIDS system, enabling seamless, high-speed connectivity between local field devices such as VIPUs, IP cameras, UPS systems, and remote-control centers (e.g., TMC). It shall support Power over Ethernet (PoE) for connected devices, deliver redundant network paths, and withstand harsh roadside environmental conditions.

Technical Specifications:

Description	Value / Requirement
Switch Type	Layer 2 or Layer 3 Managed Industrial Ethernet Switch
Ports	Minimum 8 × 10/100/1000 Mbps RJ45 ports, 2 × SFP uplink ports (1 Gbps or higher)
PoE Capability	IEEE 802.3af/at compliant (minimum 4 PoE+ ports, up to 30W per port)
Backplane Switching Capacity	≥ 16 Gbps
MAC Address Table	Minimum 8K entries
VLAN Support	IEEE 802.1Q compliant, supports ≥ 256 VLANs
Redundancy Features	Rapid Spanning Tree Protocol (RSTP), Multiple Ring Redundancy (MRP/ERPS), STP, LACP
QoS & Traffic Prioritization	IEEE 802.1p/802.1Q-based QoS, port-based traffic control, IGMP Snooping
Management Interface	Web GUI, CLI, SNMP v1/v2c/v3, Telnet/SSH
Power Input	Dual redundant 24–48V DC power input with reverse polarity and overvoltage protection
Power Consumption	≤ 60W (PoE model)
Protection & Standards	Surge protection on power and Ethernet ports; ESD ≥ 6kV; EFT ≥ 2kV
Housing	DIN-rail or wall-mount metal enclosure; fanless design
Operating Temperature	–40°C to +75°C (industrial grade)
Ingress Protection	IP30 or higher (enclosure rated for cabinet installation)
Certifications	CE, FCC Part 15 Class A, UL, RoHS, EN 61000-6-2/6-4, IEC 61850 (optional for substation use)

7.33.3.5. Electronic Cabinets

The electronic cabinets shall house and protect all vital VIDS hardware components, including the Video Image Processing Units (VIPUs), UPS units, networking modules, surge protection, and other auxiliary electronics. The cabinets must ensure environmental protection, security against tampering or vandalism, and thermal regulation to prevent equipment failure.

Technical Specifications:

Description	Value / Range
Cabinet Type	Outdoor-rated, free-standing or pole-mounted electronic equipment enclosure
Material	Stainless steel (SS304/SS316) or powder-coated galvanized steel
Protection Rating	Minimum IP66 (IEC 60529) and NEMA Type 4X
Dimensions	Approx. 800 × 600 × 300 mm (W × H × D); adjustable as per equipment need
Cooling System	Thermostatically controlled ventilation fan or heat exchanger
Internal Layout	DIN rail and tray-mounted with dedicated shelves for VIPU, UPS, and power modules
Door Locking System	Multi-point locking with tamper alarm and padlock provision
Intrusion Alarm	Magnetic door contact sensor integrated with VIPU/TMC
Cable Entry	Bottom gland plate with weather-sealed cable entries
Grounding & Earthing	Internal grounding busbar; compliance with IEEE 1100
Mounting Hardware	Pole or pad-mounting brackets; vibration-isolated clamps
Operating Temperature	–20°C to +60°C (fan-cooled); up to +70°C with passive vents
Interior Lighting	Automatic LED cabinet light (with door-open switch)
Labeling and Identification	UV-resistant engraved label plates; circuit and component identification
Compliance	IEC 62208 (empty enclosures for low-voltage switchgear), CE, RoHS

7.33.3.6. Uninterrupted Power Supply (UPS)

The Uninterrupted Power Supply (UPS) shall provide clean, stable, and backup power to the Video Incident Detection System (VIDS) components during utility power interruptions or voltage fluctuations. It shall support the continuous operation of the VIPU, camera, communication modules, warning systems, and local storage during outages, ensuring system availability for a minimum of 4 hours.

Technical Specifications:

Description	Value / Range
UPS Type	Line-interactive or online double-conversion with pure sine wave output
Rated Output Power	800W – 1000W (depending on equipment load)
Output Voltage	48V DC nominal (with DC–DC converters for 12V/24V modules)
Input Voltage Range	170–270V AC (auto-sensing)
Frequency	50Hz ± 5%
Battery Type	Sealed Lead-Acid (AGM/VRLA) or Lithium-Ion
Battery Capacity	≥ 100Ah (for 4 hours runtime at 50% load)
Charging Time	80% capacity recharge within 4–6 hours
Monitoring and Alarms	LED/LCD panel with fault, battery, load, and temperature indicators
Protection Features	Overload, short circuit, deep discharge, over-temperature
Communication Interface	RS-485 / SNMP / TCP/IP remote monitoring
Cabinet Integration	Rack or shelf-mounted inside the VIDS electronic cabinet

Operating Temperature	–10°C to +55°C
Ingress Protection	IP54 or better (when mounted inside a protected cabinet)
Compliance	IEC 62040-1 (General & Safety), IEC 61000-4-5 (Surge Immunity), CE, RoHS

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Road Safety Technical Specification: Part II

The deployment of Intelligent Transport Systems (ITS) in Bangladesh is guided by the evolving Bangladesh National ITS Master Plan for Roads and Highways Department (RHD). This plan seeks to contextualize international ITS frameworks for local applications, based on the country's current infrastructure maturity and deployable technologies. According to the 2017 UNESCAP report, six fundamental ITS service categories dominate the Asia-Pacific region:

7. Advanced Traffic Management System (ATMS)
8. Electronic Toll Collection System (ETCS)
9. Advanced Traveler Information System (ATIS)
10. Advanced Public Transportation System (APTS)
11. Emergency Management System (EMS)
12. Commercial Vehicle Operations (CVO)

Among the six ITS service categories, Advanced Traffic Management System (ATMS) stands out as the most practical, widely deployed in the Asia-Pacific region, and the most viable for implementation by the Roads and Highways Department (RHD) in the current context. ATMS serves as a core component of an Intelligent Transport System (ITS), aimed at optimizing traffic flow, enhancing road safety, and improving overall transport efficiency. It leverages a combination of sensors, communication networks, software, and control devices to achieve these goals. Key ATMS functions identified for deployment in Bangladesh include the Automated Traffic Counter and Classifier (ATCC), Security Surveillance (SS), Automated Speed Enforcement System (ASES), Variable Message Signs (VMS), Video Incident Detection Systems (VIDS), and Road Weather/Environment Information Systems (RWIS). These components work in tandem through a combination of sensors, communication infrastructure, software platforms, and control devices, offering a scalable and effective framework for advancing road safety and traffic management in Bangladesh.

Looking into the past development of ITS infrastructure and services, user-oriented services such as ATIS and APTS gained attention only after a minimum level of automated traffic management was achieved. Building on the success of mid-level ITS services, Advanced Public Transportation Systems (APTS), Advanced Traveler Information Systems (ATIS), and other advanced technologies can be considered for future deployment to further enhance traffic efficiency and road safety in Bangladesh.

Customized ITS Service Areas for Bangladesh

The draft Bangladesh National ITS Master Plan for RHD provides a generic overview of ITS services, sub-services, physical components, logical architecture, and data flow diagrams (DFDs) for various service areas. These show how ITS elements are functionally distributed across **Road segments**,

Traffic management **centers**, **traveler interfaces**, and **cooperating entities** (e.g., Police, Hospitals, Meteorological Department).

While the Bangladesh National ITS Master Plan for RHD outlines a range of service areas, not all are structured. Based on analysis and contextual feasibility, the following customized service areas and their associated ITS components are considered in this Specification for implementation in Bangladesh:

Table: ITS Service Areas and Applicable Components for Road Safety and Operations in Bangladesh

Service Area	Sub-service Areas	Applicable ITS Components
Advanced Traffic Management System (ATMS)	- Real-time traffic monitoring service - Basic transport information dissemination - Traffic/emergency/special road info (flood, congestion, blockage, accident) - Transport information management - Incident detection - Speed violation detection and speed limit enforcement - Security surveillance - Illegal stopping/parking enforcement - Road weather monitoring (e.g., fog, storm, heavy rain) - Expressway traffic flow control - Exclusive Lane guidance - Automated traffic counting and classification	ATCC, VIDS, ASES-SS, RWIS, VMS, ASES, Traffic Management Centers (TMC), Mobile Apps, Web Portals
Emergency Management Service (EMS)	- Emergency detection and response - Emergency vehicle operation support - Emergency medical support	VIDS, VMS, Emergency Communication Systems (Emergency Call Boxes, Mobile Communication System), Traffic Management Centers (TMC)/Call Center, Web portal
Electronic Toll Collection (ETCS)	- Electronic toll payment - Congestion tolls	RFID Readers, DSRC Units, ATCC, VMS, Toll Management

	- Parking fee collection - Public transport fare collection	Centers, Mobile Apps, Web portal
Commercial Vehicle Operations (CVO)	- Overweight vehicle enforcement - Load restriction - Dangerous goods and overloaded freight management	RFID Readers, DSRC Units, VMS, Weighbridges, ATCC, ALCS Management Centers

From Function to Specification

Based on the customized ITS service areas, sub-service functions, and deployable technologies in the context of Bangladesh, this Technical Specification includes the following components:

- Video Incident Detection System (VIDS)
- Automated Speed Enforcement System (ASES) integrated with Security Surveillance (SS)
- Road Weather/Environment Information System (RWIS)
- Emergency management System (EMS)
- Electronic Toll Collection System (ETCS)
- Overload Control System
- Variable Message Signs (VMS)
- Automated Traffic Counter and Classifier (ATCC)
- Traffic Management Center (TMC)
- Optical Fiber Communication (OFC) Network

Each component included in this document is detailed in terms of its functional role within the broader ITS architecture, the physical components required for deployment (such as sensors, controllers, and cameras), performance requirements based on relevant operational standards, and clearly defined measurement and payment items to ensure accurate budgeting and accountability for contractors. This structured approach ensures alignment with international ITS best practices while remaining responsive to the practical and scalable deployment needs of Bangladesh.

7.33. Video Incident Detection Systems (VIDS)

The Video Incident Detection System (VIDS) is a key element of RHD's Intelligent Transport System (ITS), aligned with the Bangladesh National ITS Master Plan to suit local infrastructure and deployment needs. Powered by artificial intelligence (AI), machine learning (ML), and computer vision techniques, the VIDS platform automatically detects and categorizes a wide range of traffic incidents, including stopped vehicles, collisions, jaywalking, wrong-way driving, and fire/smoke hazards, using high-resolution video analytics. The system is designed to provide timely alerts and detailed event metadata to the central/regional Traffic Management Centers (TMCs), thereby improving situational awareness and operational response.

This specification outlines the complete technical and operational framework for deploying VIDS, including system functionality, detection capabilities, hardware and software architecture, and integration with TMCs. It also covers edge and cloud processing requirements, along with provisions for data management, security, resilience, accuracy, and interoperability. The VIDS platform is designed to enhance road safety, optimize traffic flow, and support data-driven management of RHD highways.

7.33.1. Generic Requirements

The primary objective of VIDS is to enable continuous, automated detection of critical or abnormal roadway incidents at key locations, junctions, or traffic entities, as determined by the Engineer, for real-time detection (with a minimum acceptable detection accuracy), verification, and response.

Typical VIDS deployment locations include, but are not limited to:

- Critical junctions and intersections where signal violations, wrong-way entries, or vehicle-pedestrian conflicts are common.
- Tunnel entrances/exits, flyovers, bridges, and underpasses, where traffic conditions can change rapidly.
- Toll plaza approaches and egress zones, where vehicle queuing, sudden stops, and congestion buildup are frequent.
- Pedestrian-heavy areas such as market zones, bus terminals, school zones, and crossings susceptible to jaywalking or crowd-related disruptions.
- Weaving areas and merge/diverge zones where abrupt lane changes and deceleration increase crash risk.
- Accident-prone segments, blackspots, and crash clusters identified through historical data or road safety audits.

All VIDS locations shall be selected in coordination with RHD's Road Design and Safety Circle and shall be integrated with the nearest Traffic Management Center (TMC) for efficient processing, notifying, and archiving.

7.33.2. Technical and Functional Requirements

7.33.2.1. Definition of Traffic Incidents for VIDS

A traffic incident, for the purpose of the Video Incident Detection System (VIDS) under the Intelligent Transport System (ITS) framework of the Roads and Highways Department (RHD) of Bangladesh, can be defined as:

“An unplanned, non-recurring event occurring on or near the roadway that leads to a reduction in roadway capacity, abnormal traffic flow, or elevated safety risks to road users. Such incidents may involve physical obstructions or behavioral disruptions and include, but are not limited to, vehicle collisions, stalled or slow-moving vehicles, unauthorized pedestrian crossings (jaywalking or chicken runs), fire or smoke on the roadway, fallen objects, erratic driving behavior, and spontaneous traffic congestion.”¹⁷

Planned roadway activities, such as routine maintenance or construction projects, are explicitly excluded from this definition. Likewise, large-scale emergencies, such as natural disasters or terrorist attacks, while they may affect traffic flow, fall outside the detection scope of VIDS due to their broader emergency management implications and multi-domain impact beyond the roadway environment. While VIDS is a critical subsystem for the automated detection of such incidents, it does not perform functions such as security surveillance, speed enforcement, or environmental hazard detection (e.g., fog, rain). These functions fall under other ITS components deployed by RHD, including:

- Security Surveillance Systems (SS)
- Automated Speed Enforcement Systems (ASES)
- Road Weather Information Systems (RWIS)

Integration of VIDS with these complementary ITS subsystems is addressed in other sections of this specification.

¹⁷ This definition is adapted from *Gordon (2016)* and harmonized with the incident management principles of the *National Incident Management System (NIMS)* and *Incident Command System (ICS)*, which establish a standardized, scalable framework for incident response across all levels of government and agencies (*FEMA, 2017*).

7.33.2.2. Incident Management and Classification Framework

The Video Incident Detection System (VIDS) shall incorporate a structured, interoperable framework for incident reporting and classification, in alignment with the National Incident Management System (NIMS) and its associated Incident Command System (ICS), as established by the U.S. Department of Homeland Security and described in Chapter 6I of the Manual on Uniform Traffic Control Devices (MUTCD).

According to NIMS and MUTCD guidelines, traffic incidents shall be classified into three categories based on their **expected duration** and operational impact:

- **Minor Incident** (Duration < 30 minutes)
Typically does not require extensive scene management or lane closure.
Examples: Disabled vehicles, minor property-damage crashes, small road debris
- **Intermediate Incident** (Duration 30 minutes to 2 hours)
Requires temporary traffic control and moderate response coordination.
Examples: Multi-vehicle crashes, injury crashes, overturned light vehicles
- **Major Incident** (Duration > 2 hours)
Causes full or partial closure and requires a coordinated multi-agency response.
Examples: Fatal crashes, hazardous materials spills, truck rollovers, infrastructure damage, fire/smoke

The duration classification reflects not only the time to clear the incident physically but also the time required to restore safe and normal traffic operations (*National Incident Management System, FEMA; MUTCD Chapter 6I – Traffic Incident Management*).

7.33.2.3. Classification of VIDS-detectable Incidents

The Roads and Highways Department (RHD) has defined a set of traffic incidents to be automatically detected, reported, and classified by the Video Incident Detection System (VIDS) deployed under its Intelligent Transport System (ITS) framework. These incident types represent common and critical non-recurring roadway events that impact traffic safety and flow. The VIDS shall detect the defined events in real time and classify them according to the duration-based categories, Minor, Intermediate, and Major, outlined in the National Incident Management System (NIMS) and MUTCD Chapter 6I, as summarized in Table 7.33-1.

Table 7.33-1: VIDS incident types and NIMS classification

VIDS Incident Type	NIMS Classification	Remarks
Disabled vehicle or illegal stop	Minor	Typically cleared within 30 minutes
Jaywalking / Chicken run	Minor	No vehicle impact unless a collision occurs
Falling or dropped object	Minor / Intermediate	Duration varies with object type and removal time
Vehicle stopped in active lane	Intermediate	May require traffic control support
Queue formation and congestion buildup	Intermediate	Requires ongoing monitoring, may escalate
Minor collision (no injury)	Minor /	Based on damage and blockage
Movement or gathering of people on the roadway/ Road block	Minor / Intermediate	May create a pedestrian hazard or delay; risk depends on location/context
Speed drop / sudden deceleration	Intermediate	Could indicate an incident or hazard ahead; requires system-generated alert
Environmental hazard (fog/flood/storm detection) ¹⁸	Intermediate / Major	Triggers visibility-related alerts; risk level depends on severity/location
Multi-vehicle crash or injury crash	Intermediate/ Major	May require emergency service response
Wrong-direction vehicle movement (reverse or across	Major	High risk, requires immediate alert and intervention
Fire or smoke from a vehicle or roadside	Major	Life-threatening; full emergency response required
Fatal crash or hazardous spill	Major	Critical incident with multi-agency coordination
Overtaken truck or large commercial vehicle	Major	Road blockage and safety risk

Note: Adapted from *National Incident Management System* (3rd ed., p. XX), by Federal Emergency Management Agency, 2017, U.S. Department of Homeland Security

7.33.2.4. Incident Command System (ICS) Integration

The Video Incident Detection System (VIDS) shall support the core principles of the Incident Command System (ICS), which include standardized communication protocols, unified multi-agency

¹⁸ This incident, though tabulated for VIDS detectable incidents, is objectively detected through the Road Weather Information System (RWIS)

command, real-time incident documentation, and operational coordination. VIDS shall be fully interoperable with Traffic Management Centers (TMCs) and shall generate structured incident data to support all relevant stages of the incident management lifecycle, from detection to recovery and termination.

By design, VIDS enhances the capability of TMCs to manage incidents in accordance with ICS-based workflows. It provides the foundational data layer for detection, classification, communication, situational assessment, and archival, enabling more effective coordination between emergency services (e.g., traffic police, fire services, emergency medical services), highway authorities, and other ITS subsystems.

VIDS shall enable the following core functionalities:

- **Automatic alerting** to TMCs and emergency response units upon incident detection
- **Generation of structured incident records**, including incident type, severity, location, time, lane occupancy, and estimated duration
- **Real-time situational awareness** through continuous video feeds and incident updates for use by the designated **Incident Commander**
- **Support for Unified Command**, allowing multiple stakeholders to access incident status, share common objectives, and coordinate response efforts
- **Plain-language communication**- ensuring incident data is free from radio codes or agency-specific jargon, facilitating cross-agency clarity
- **Inter-agency compatibility** of all alert messages, logs, and archived data formats for use in audits, training, and policy review

Table 7.33-2 below summarizes how VIDS supports each stage of incident management.

Table 7.33-2: VIDS-Supported Incident Management Functions and Stages (adapted from (Gordon, R., 2015)).

VIDS-Supported Incident Management Function	Detection & Verification	Response	Clearance	Recovery
Detect an incident and identify its properties (e.g., lane blockage, location, direction)	√			
Classify incident into type and severity (Minor / Intermediate / Major – as per NIMS classification)	√			
Notify responding agencies of incident metadata (location, type, estimated duration, severity)	√	√		
Enable integrated alert dissemination to motorists via VMS, mobile alerts, and web portal (when interfaced)		√	√	√

Provide traffic conditions and/or route guidance to responding agencies		√	√	√
Archive incident video and data for post-event review, analysis, planning, and auditing (incident logs, timestamps, evidence snapshots)			√	√
Enable or support confirmation of incident clearance through visual verification			√	√
Close the incident record with the final log entry and mark it for archival				√

7.33.2.5. Role of CCTV in Incident Detection and Location Prioritization

Closed-Circuit Television (CCTV) surveillance has proven to be one of the most effective tools for incident detection and verification in Intelligent Transport Systems (ITS). Compared to traditional methods such as emergency calls or manual patrols, CCTV enables faster detection of incidents by continuously monitoring roadway conditions in real time. It not only detects events but also verifies incident characteristics on an evidence basis, allowing Traffic Management Centers (TMCs) to assess severity and dispatch the appropriate response quickly. This combination of detection and visual verification minimizes response time and improves coordination with emergency services.

The relationship between CCTV deployment coverage, system benefit, and installation cost is illustrated in Figure 7.33-1 below. The graph demonstrates that:

- The marginal benefit of CCTV increases rapidly in early deployment stages, especially in high-demand corridors (Curve A).
- Beyond 70–80% coverage, the benefit curve flattens, indicating diminishing returns.
- Meanwhile, the cost curve (C) increases exponentially due to overlapping coverage and infrastructure intensification.
- Therefore, net benefit is maximized when coverage is strategically targeted rather than uniformly distributed.

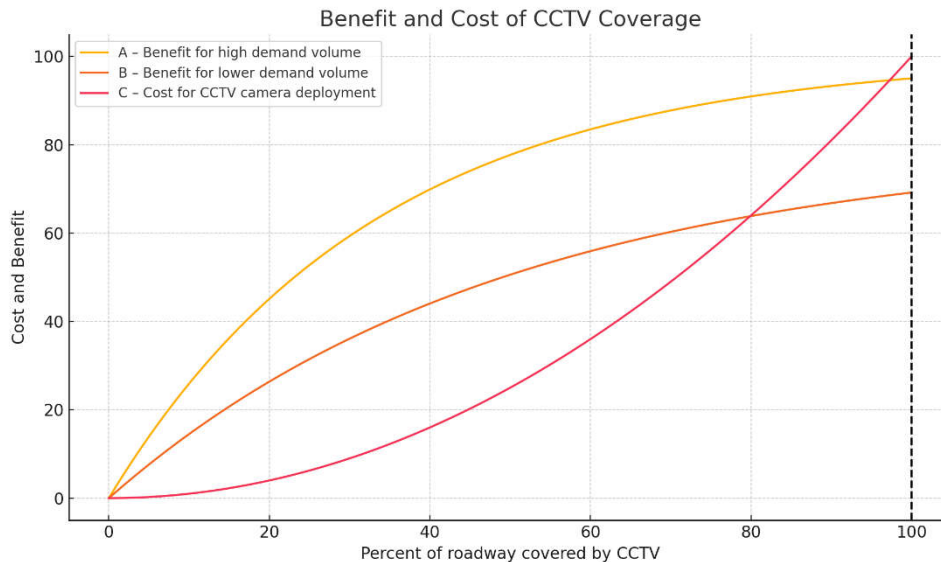


Fig. 7.33-1: Benefit and Cost of CCTV Coverage based on Percent of Roadway Covered
Source: Adapted from *Region 4 ATMS Local Evaluation Report*, Dunn Engineering Associates, 2005.

Based on the cost-benefit analysis illustrated in Figure 7.33-1, full CCTV coverage across all roadway segments is not economically optimal due to diminishing returns at higher coverage levels and escalating infrastructure costs. Therefore, the Roads and Highways Department (RHD) shall adopt a targeted deployment strategy that prioritizes surveillance where it delivers the highest benefit per unit cost.

CCTV coverage shall be focused on roadway segments with elevated traffic volumes, high incident probability, or strategic importance. Priority locations include:

- High-incident areas such as intersections, interchanges, and accident blackspots
- Traffic bottlenecks, including freeway ramps and weaving zones
- Critical infrastructure such as toll plazas, tunnels, bridges, and roadside facilities
- High-volume corridors where peak-hour traffic operates at Level of Service (LOS) C or worse

This approach ensures cost-efficient deployment, while preserving high standards for real-time incident detection, traffic monitoring, and coordinated response.

7.33.2.6. CCTV Camera Optical and Placement Requirements for VIDS

To ensure consistent incident detection performance across varying environmental and lighting conditions, all CCTV cameras used in the Video Incident Detection System (VIDS) shall conform to the following technical parameters based on IEC EN 62676-4:2015 (DORI model) and international ITS deployment practices:

DORI-Based Optical Performance

DORI (Detection, Observation, Recognition, Identification) is an industry standard that defines the level of detail in PPM (Pixel Per Meter) required for a visible surveillance camera to obtain Detection, Observation, Recognition, Identification. The camera's optical system shall support surveillance and analytics at the following minimum pixel density levels, defined in Pixels Per Meter (PPM) at the target area:

Table 7.33-3: DORI-based image quality requirements for CCTV cameras in VIDS

DORI Level	Purpose	Required PPM	Function in VIDS
Detection	Identify object presence	≥ 25 PPM	Basic motion/stopped vehicle detection
Observation	Detect shape, direction, and activity	≥ 62 PPM	Wrong-way driving, queue formation, object drop
Recognition	Match a known vehicle or person	≥ 125 PPM	Confirm returning violator or suspect behavior
Identification	Determine identity beyond doubt	≥ 250 PPM	License plate, facial, or branding verification

These levels must be achieved under daylight and night illumination at the intended coverage range of the camera (typically 100–200 meters) [IEC EN 62676-4:2015].

Resolution and Focal Length

The required pixel density shall be verified through calculations based on camera resolution, field of view, distance to target, and mounting height. However,

- Cameras shall have a minimum resolution of 4 MP (2688×1520) for general-purpose incident detection, and 5 MP or higher for applications requiring object recognition or license plate capture [IEC EN 62676-4:2015].
- Lens focal length shall be selected based on the required DORI range:
 - 2.8–4 mm for wide-angle FOV in short-range urban settings
 - 8–50 mm (or motorized zoom) for highways and narrow corridor coverage [FHWA, 2009]

Field of View and Target Coverage

- Cameras shall be configured to provide a horizontal Field of View (FOV) suitable for the number of lanes to be covered (typically 2–3 lanes).

- The FOV width at the detection plane shall correspond to the required PPM level and resolution. However, the effective detection and surveillance range of each camera shall be not less than 100 meters and not more than 200 meters to ensure optimal object detection and video analytics performance.
- The horizontal angle shall be selected such that the effective detection zone maintains high sharpness at the image center.
- Mounting height, target height, and viewing angle shall be coordinated to eliminate parallax errors and obstruction by large vehicles.

Mounting and Environmental Suitability

- All cameras shall be installed at a height of 8–12 meters, ensuring clear line-of-sight and minimizing obstruction and occlusion problems during the detection process.
- In environmentally challenging areas, cameras shall be equipped with:
 - Infrared (IR) or Near-Infrared (NIR) illumination for low-light performance
 - Wide Dynamic Range (WDR) or High Dynamic Range (HDR) sensors to manage glare, shadows, and varied lighting

Camera Overlap Zones

- Adjacent cameras shall be installed with an overlap of 10% to 15% of their horizontal field of view.
- Overlap shall be provided to eliminate blind spots, support vehicle tracking across zones, and enhance incident confirmation.
- The overlap shall be verified during system commissioning through calibration and test viewing angles [NCHRP, 2014].

An example overview to select FOV based on DORI is given in Figure 7.33-2. The camera height, distance, focal length, resolution, and related parameters for the intended purposes of VIDS shall be analyzed using such online available toolkits (example link: <https://www.jvsg.com/calculators/cctv-lens-calculator/>) before finalizing the selection of and placement of the specific camera models.

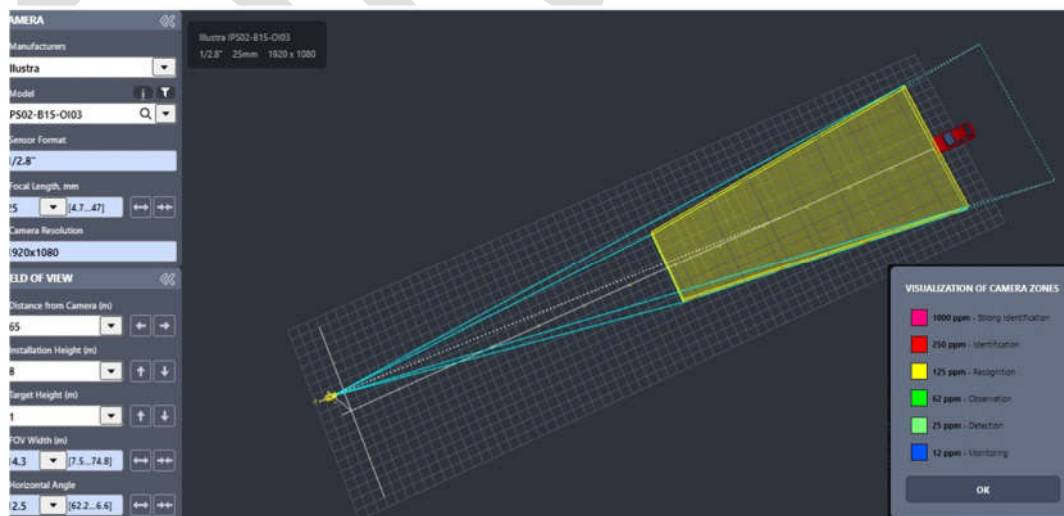
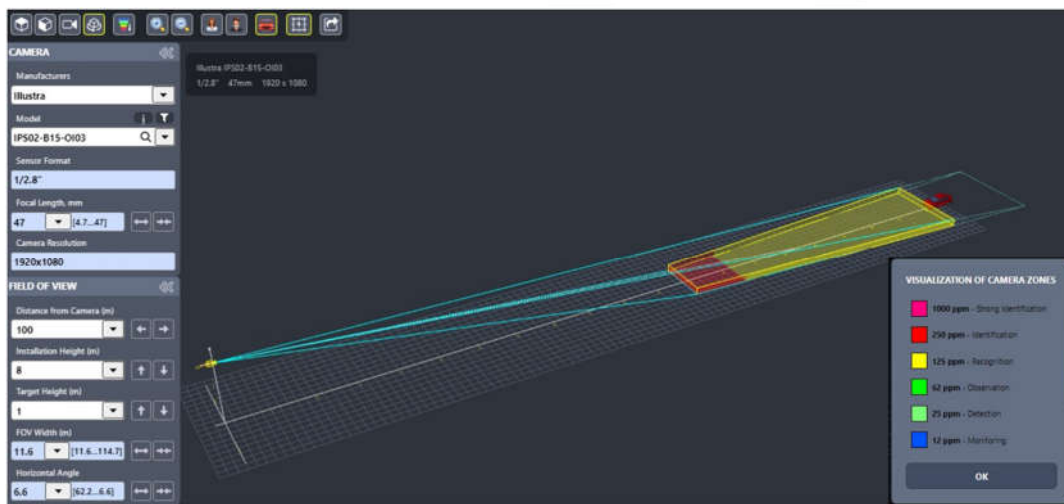
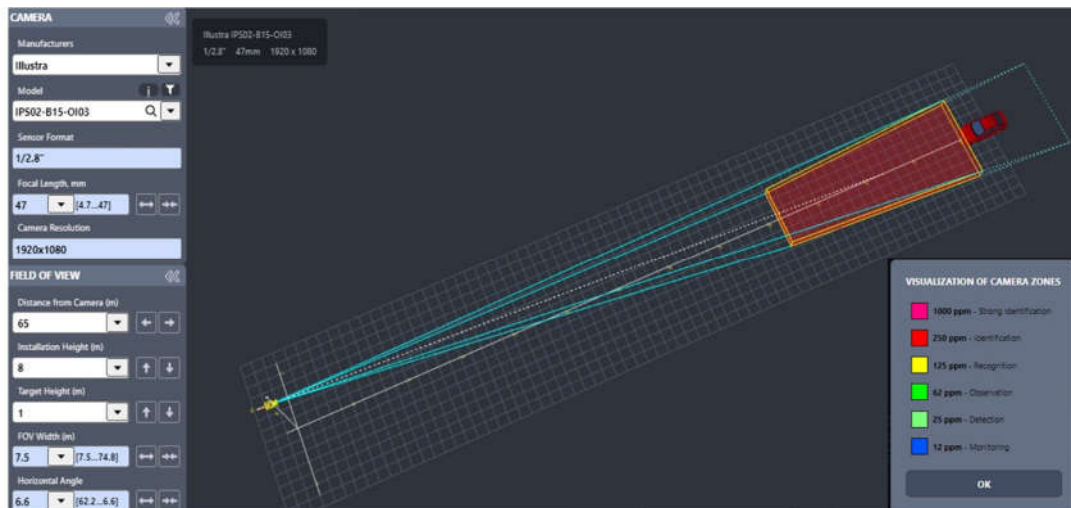


Figure 7.33-2: DORI-based identification of FOV and

7.33.3. Hardware Requirements

The Video Incident Detection System (VIDS) shall be supported by a robust, scalable, and resilient hardware infrastructure designed for 24/7 real-time monitoring, automated incident detection, edge-based video analytics, alert generation, and data communication across strategic highway corridors under the Roads and Highways Department (RHD) of Bangladesh. The system must ensure high availability, operational continuity, and resistance to environmental extremes, electrical surges, and vandalism typical of roadside deployments.

The following sub-components have been selected to meet the demanding environmental and operational conditions of national highways while ensuring seamless system integration, high performance, and long-term reliability.

16. **Local (Video Image) Processing Unit (LPU)** - On-site edge analytics module for multi-lane incident detection using AI and deep learning.
17. **Video Surveillance Camera with IR Filter and Sunshield and Self-cleaning/ maintenance assist system** - High-resolution, weatherproof cameras for 24/7 video feed and analytics support with automated lens cleaning or hydrophobic coatings for environments prone to dust, fog, or pollution.
18. **Pole/Gantry-Mounted Flashing Warning Lights** - High-intensity LED beacons for alerting motorists of active incidents.
19. **High-Performance Industrial Network Switch** - Managed Ethernet switches with PoE and redundancy for stable field-to-TMC communication.
20. **Electronic Equipment Cabinets** - Outdoor-rated enclosures to house VIPUs, UPS, network devices, and associated hardware.
21. **Uninterrupted Power Supply (UPS)** - A Backup power system ensuring continuous operation for at least 4 hours during outages.
22. **Solar Lighting Units** - Energy-efficient illumination for remote sites or supplemental visibility at night.
23. **Hooter Alarms and Signal Systems** - Audible alerts triggered during high-risk incidents (e.g., fire, wrong-way driving).
24. **Power Connection Arrangement** - Grid-based or off-grid structured power delivery system with circuit protection and ATS integration.
25. **OFC / ISP Communication Arrangement** - High-speed fiber or cellular backhaul infrastructure for real-time data exchange with TMC.
26. **Anti-Theft Protection System** - Physical deterrents and intrusion monitoring to prevent unauthorized access or equipment theft.
27. **Redundant Power Switching Module** - Automatic source switching between grid, UPS, and solar inputs for uninterrupted functionality.

28. **Motion Detection Camera for Intrusion Alarm** - Surveillance to detect unauthorized activity around sensitive field assets.
29. **Lightning Arrestor** - Surge diversion device to prevent equipment damage from lightning strikes.
30. **Surge Protection and Grounding System** - Integrated SPD and grounding network to shield equipment from electrical surges and ensure safety.

7.33.3.1. Local Video Image Processing Unit (VIPU)

The Local Video Image Processing Unit shall serve as the intelligent core of the VIDS system, performing high-speed, on-site video analytics for incident detection, traffic monitoring, and real-time alert generation. It shall operate independently or in coordination with the TMC and support continuous processing from multiple high-resolution camera feeds. The VIPU shall include integrated AI acceleration to support real-time deep learning inference for edge-based detection of multiple incident types.

Technical Specifications:

Description	Value / Requirement
Processor	6-12 core NVIDIA Arm® Cortex A78 v8. (e.g., NVIDIA Carmel) or equivalent high-performance embedded CPU with > 2.0 GHz frequency
GPU / Edge AI Accelerator	Integrated NVIDIA Ampere GPU with ≥ 1024 CUDA cores and 32 Tensor Cores, ≥ 100 TOPS AI performance at > 1GHz
AI Framework Support	TensorRT, CUDA, cuDNN, OpenCV, ONNX Runtime, PyTorch
Video Channels	Support for processing at least four (04) simultaneous 1080p video feeds
AI Functionality	Multi-lane vehicle detection, wrong-way movement, stopped vehicle, queue buildup, pedestrian detection, smoke/fog analysis
RAM	Minimum 16 GB LPDDR5
Storage	256 GB eMMC or NVMe SSD support up to 1TB, expandable (with edge buffer support for offline storage)
Network Interface	Dual Gigabit Ethernet with VLAN support; RJ45 ports; support for PoE
Input Ports	CSI or GMSL inputs (supporting high-def camera integration)
Output Ports	HDMI for local display, optional serial or GPIO for alarm signaling
OS and Software	Ubuntu 20.04 LTS or equivalent Linux-based distribution with preloaded VIDS software framework and remote OTA update capability
Communication Protocols	TCP/IP, HTTP(S), FTP, SNMP, MQTT, ONVIF, RTSP
Alarm Handling	Real-time alert generation; support for programmable rules and triggers
Mounting	DIN rail, shelf, or inside electronic cabinet

Power Supply	12–24V DC input, ≤ 60W power consumption (fanless or passive cooling preferred)
Operating Temperature	–20°C to +65°C
Ingress Protection	IP30 or higher (indoor protected cabinet); protected from dust and vibration
Security Features	Secure boot, firmware encryption, hardware-level watchdog
Compliance	CE, RoHS, FCC, EN55032/35 Class A, IEC 61000-4

7.33.3.2. Video Camera(s) with IR Filter, Enclosure, and Sunshield

The VIDS surveillance camera shall be used for 24/7 video capture in all lighting and environmental conditions. It shall support advanced video analytics for detecting abnormal traffic behavior, including stopped vehicles, jaywalking, falling objects, queue formation, and speed anomalies. The camera shall be suitable for outdoor mounting on poles or gantries and shall integrate seamlessly with the VIPU.

Technical Specifications:

Description	Value / Range
Image Sensor	1/2.8" Progressive Scan CMOS
Resolution	Minimum 4 MP (2688 × 1520)
Shutter Speed	1/3 s to 1/100,000 s (suitable for moving objects)
Minimum Illumination	0.01 Lux @ F1.2 (color); 0 Lux with IR
IR Illumination	Integrated IR LEDs with a minimum 50 m range
Lens	Motorized varifocal, 2.8–16 mm (optional 8–32 mm for highway)
Lens Mount	M12 or CS-mount
Wide Dynamic Range (WDR)	≥ 120 dB
Frame Rate	30 fps at full resolution, > 50 fps for highways
Compression Format	H.265 / H.264 / MJPEG
Video Analytics Support	Compatible with VIPU detection zones; edge-based basic analytics enabled
Communication Interface	RJ45 10/100 Ethernet; ONVIF Profile S/G compliant
Operating Temperature	–30°C to +60°C
Housing Protection	IP67-rated weatherproof, IK10 vandal-resistant metal enclosure
Sunshield	Removable or integrated, anti-glare design
Power Supply	PoE (IEEE 802.3af/at) or 12V DC ±10%
Power Consumption	Max 15 W with IR ON
Certifications	CE, FCC, RoHS, ONVIF, UL

For locations subject to dust, fog, bird activity, or salt spray, the camera shall optionally include a built-in lens cleaning system. This may consist of a wiper/nozzle-based solution or an advanced hydrophobic

lens coating to ensure continuous visibility and maintain image clarity. Cleaning cycles shall be remotely configurable from the Traffic Management Center (TMC).

Self-Cleaning / Maintenance-Assist System (Optional but Recommended)

Feature	Specification
Cleaning Type	Lens-integrated nozzle spray system, wiper-based mechanism, or hydrophobic coating
Control Trigger	Manual via TMC command or scheduled periodic cleaning via timer/controller
Water Tank / Fluid Type	Non-abrasive lens cleaning solution (min. 1 liter capacity if tank-based)
Integration	Integrated with camera housing or mount arm; compatible with camera control unit
Maintenance Interval	Minimum 100 cleaning cycles without refill (tank-based); continuous (coating)
Operating Temperature	-20°C to +60°C; UV- and corrosion-resistant
Optional Add-On	Automatic rain/fog sensing trigger

7.33.3.3. Pole/Gantry-Mounted Flashing Warning Lights

The flashing warning lights shall provide visible alerts to motorists in the event of an incident detected by the VIDS. These lights are crucial for warning approaching vehicles of hazardous situations like wrong-way movement, stopped vehicles, fire/smoke, or congestion. They shall be integrated with the VIDS system and activated automatically via incident detection from the VIPU.

Technical Specifications:

Description	Value / Range
Light Type	High-intensity LED beacon
Illumination Color	Amber (preferred for highway safety) or Red (in special zones)
Visibility Range	Minimum 500 meters in clear atmospheric conditions
Flash Rate	1–2 Hz (60–120 flashes per minute)
Light Intensity	≥ 200 cd (candela), adjustable
Beam Angle	120° horizontal, 60° vertical
Mounting Compatibility	Suitable for installation on 3"–4" diameter poles or gantry arms
Housing Protection	IP66 or higher, UV-stabilized polycarbonate lens with aluminum base
Operating Temperature	-40°C to +60°C
Control Interface	Dry contact input or TCP/IP signal from VIPU or TMC systems
Synchronization	Supports multiple lights flashing in unison for wide-area alerts
Power Supply	12V or 24V DC; solar-capable or UPS integrated
Power Consumption	≤ 15W per unit
Compliance	MUTCD Chapter 4K.02 and EN 12352 (where applicable)
Expected Lifespan	≥ 50,000 hours (LED lifetime)

7.33.3.4. High-Performance Industrial Network Switch

The Industrial Network Switch shall serve as a robust and reliable data communication backbone for the VIDS system, enabling seamless, high-speed connectivity between local field devices such as VIPUs, IP cameras, UPS systems, and remote-control centers (e.g., TMC). It shall support Power over Ethernet (PoE) for connected devices, deliver redundant network paths, and withstand harsh roadside environmental conditions.

Technical Specifications:

Description	Value / Requirement
Switch Type	Layer 2 or Layer 3 Managed Industrial Ethernet Switch
Ports	Minimum 8 × 10/100/1000 Mbps RJ45 ports, 2 × SFP uplink ports (1 Gbps or higher)
PoE Capability	IEEE 802.3af/at compliant (minimum 4 PoE+ ports, up to 30W per port)
Backplane Switching Capacity	≥ 16 Gbps
MAC Address Table	Minimum 8K entries
VLAN Support	IEEE 802.1Q compliant, supports ≥ 256 VLANs
Redundancy Features	Rapid Spanning Tree Protocol (RSTP), Multiple Ring Redundancy (MRP/ERPS), STP, LACP
QoS & Traffic Prioritization	IEEE 802.1p/802.1Q-based QoS, port-based traffic control, IGMP Snooping
Management Interface	Web GUI, CLI, SNMP v1/v2c/v3, Telnet/SSH
Power Input	Dual redundant 24–48V DC power input with reverse polarity and overvoltage protection
Power Consumption	≤ 60W (PoE model)
Protection & Standards	Surge protection on power and Ethernet ports; ESD ≥ 6kV; EFT ≥ 2kV
Housing	DIN-rail or wall-mount metal enclosure; fanless design
Operating Temperature	–40°C to +75°C (industrial grade)
Ingress Protection	IP30 or higher (enclosure rated for cabinet installation)
Certifications	CE, FCC Part 15 Class A, UL, RoHS, EN 61000-6-2/6-4, IEC 61850 (optional for substation use)

7.33.3.5. Electronic Cabinets

The electronic cabinets shall house and protect all vital VIDS hardware components, including the Video Image Processing Units (VIPUs), UPS units, networking modules, surge protection, and other auxiliary electronics. The cabinets must ensure environmental protection, security against tampering or vandalism, and thermal regulation to prevent equipment failure.

Technical Specifications:

Description	Value / Range
Cabinet Type	Outdoor-rated, free-standing or pole-mounted electronic equipment enclosure
Material	Stainless steel (SS304/SS316) or powder-coated galvanized steel
Protection Rating	Minimum IP66 (IEC 60529) and NEMA Type 4X
Dimensions	Approx. 800 × 600 × 300 mm (W × H × D); adjustable as per equipment need
Cooling System	Thermostatically controlled ventilation fan or heat exchanger
Internal Layout	DIN rail and tray-mounted with dedicated shelves for VIPU, UPS, and power modules
Door Locking System	Multi-point locking with tamper alarm and padlock provision
Intrusion Alarm	Magnetic door contact sensor integrated with VIPU/TMC
Cable Entry	Bottom gland plate with weather-sealed cable entries
Grounding & Earthing	Internal grounding busbar; compliance with IEEE 1100
Mounting Hardware	Pole or pad-mounting brackets; vibration-isolated clamps
Operating Temperature	–20°C to +60°C (fan-cooled); up to +70°C with passive vents
Interior Lighting	Automatic LED cabinet light (with door-open switch)
Labeling and Identification	UV-resistant engraved label plates; circuit and component identification
Compliance	IEC 62208 (empty enclosures for low-voltage switchgear), CE, RoHS

7.33.3.6. Uninterrupted Power Supply (UPS)

The Uninterrupted Power Supply (UPS) shall provide clean, stable, and backup power to the Video Incident Detection System (VIDS) components during utility power interruptions or voltage fluctuations. It shall support the continuous operation of the VIPU, camera, communication modules, warning systems, and local storage during outages, ensuring system availability for a minimum of 4 hours.

Technical Specifications:

Description	Value / Range
UPS Type	Line-interactive or online double-conversion with pure sine wave output
Rated Output Power	800W – 1000W (depending on equipment load)
Output Voltage	48V DC nominal (with DC–DC converters for 12V/24V modules)
Input Voltage Range	170–270V AC (auto-sensing)
Frequency	50Hz ± 5%
Battery Type	Sealed Lead-Acid (AGM/VRLA) or Lithium-Ion
Battery Capacity	≥ 100Ah (for 4 hours runtime at 50% load)
Charging Time	80% capacity recharge within 4–6 hours
Monitoring and Alarms	LED/LCD panel with fault, battery, load, and temperature indicators
Protection Features	Overload, short circuit, deep discharge, over-temperature
Communication Interface	RS-485 / SNMP / TCP/IP remote monitoring
Cabinet Integration	Rack or shelf-mounted inside the VIDS electronic cabinet

Operating Temperature	–10°C to +55°C
Ingress Protection	IP54 or better (when mounted inside a protected cabinet)
Compliance	IEC 62040-1 (General & Safety), IEC 61000-4-5 (Surge Immunity), CE, RoHS

7.33.3.7. Solar lights

The solar light shall be used to provide independent, energy-efficient illumination for VIDS infrastructure zones where power supply is limited or as a supplemental lighting source for camera visibility and maintenance safety. The system must be self-sustained, weatherproof, and equipped with battery storage to operate throughout the night and during low-sunlight conditions.

Technical Specifications:

Description	Value / Range
Solar Panel Type	High-efficiency monocrystalline silicon
Solar Panel Output	Minimum 100W, $\geq 20\%$ conversion efficiency
Battery Type	Lithium Iron Phosphate (LiFePO ₄) or Lithium-Ion (maintenance-free)
Battery Capacity	$\geq 500\text{Wh}$ (supports > 2 nights backup autonomy)
Light Fixture	Integrated LED luminaire with motion-sensing and auto-dimming
Light Output	≥ 5000 lumens; 5700K (cool white)
Control System	Smart controller with dusk-to-dawn operation, MPPT charging, and auto-dimming
Operating Time	Full brightness ≥ 8 hours; dimmed ≥ 24 hours with motion-based activation
Motion Sensor Range	PIR sensor with 5–8 meters detection
Mounting Height	6–10 meters, integrated pole mount or adjustable arm
Material & Housing	Die-cast aluminum, IP66-rated for outdoor use
Operating Temperature	–20°C to +60°C
Protection Features	Overcharge, deep discharge, reverse polarity, temperature protection
Communication Interface	Optional RS-485 / GSM / IoT module for remote status monitoring
Certifications	IEC 61215 (PV panel), IEC 62133 (battery), CE, RoHS, IP66, IK08

7.33.3.8. Hooter Alarms and Signal System

The Hooter Alarm and Signal System shall provide immediate audible alerts at the incident site when triggered by the VIDS. These alarms serve to warn nearby road users and maintenance staff of potential hazards such as wrong-way vehicles, stopped vehicles, or fire/smoke conditions. The system shall be integrated with the Video Image Processing Unit (VIPU) and function autonomously or via command from the Traffic Management Center (TMC).

Technical Specifications:

Description	Value / Range

Hooter Type	Electronic piezoelectric or electro-mechanical siren
Sound Pressure Level (SPL)	≥ 110 dB at 1 meter
Frequency Range	400 Hz to 1200 Hz (multi-tone)
Operating Modes	Pulse / Continuous / Alternating
Signal Activation	Controlled via dry contact relay or digital signal from VIPU or TMC
Flashing Beacon Integration	Optional integration with strobe or flashing LED light
Housing Protection	IP65 or higher; UV-resistant polycarbonate or metal enclosure
Mounting	Suitable for pole or gantry installation using anti-vibration clamps
Operating Temperature	-20°C to $+60^{\circ}\text{C}$
Power Supply	12V or 24V DC (UPS or solar-compatible)
Power Consumption	≤ 20 W
Cable Interface	Shielded cable with waterproof connectors
Audible Range	≥ 100 meters under normal traffic noise
Compliance	IEC 61000-6-1/3 (EMC), EN 54-3 (where applicable), CE

7.33.3.9. Power Connection Arrangement

The VIDS shall be provided with a robust and secure power connection arrangement to ensure a continuous and stable power supply to all field components. This shall include tapping from the nearest reliable grid source (11kV or 400V feeder), connection through a certified service drop, and routing via armored underground cables or protected surface-mounted conduits. Proper circuit isolation using industrial-grade miniature circuit breakers (MCBs), surge protection devices (SPDs), and automatic transfer switches (ATS) for backup power integration shall be implemented. All connections shall comply with the Bangladesh National Building Code (BNBC) electrical standards and IEC 60364 wiring regulations, ensuring grounding, short-circuit protection, and thermal safety. Dedicated earth pits and earthing rods shall be installed for lightning protection and equipment safety. Each site shall include an outdoor-rated electrical distribution box housed within the equipment cabinet.

7.33.3.10. OFC/ISP Connection Arrangement

The VIDS field setup shall be connected to the central Traffic Management Center (TMC) using high-speed, secure, and redundant data communication links. Optical Fiber Cable (OFC) shall be the primary medium, utilizing single-mode fiber with a minimum 1 Gbps transmission capacity to ensure uninterrupted real-time video and data transmission. Where OFC is unavailable, a secondary link using industrial-grade 4G/5G LTE or microwave backhaul (via authorized Internet Service Providers) may be provisioned. All cables shall be routed through underground conduits or overhead where applicable, with termination in weatherproof fiber enclosures. Fiber splicing, patch panels, and media converters shall follow ITU-T G.652D and ISO/IEC 11801 standards. Secure network switches and routers supporting VLANs, firewalls, and QoS shall be installed to manage and prioritize traffic. Provisions

shall also include remote configuration access and health monitoring via the TMC, ensuring compliance with national telecom and data security guidelines.

7.33.3.11. Anti-theft Protection

To safeguard all critical roadside equipment installed under the Video Incident Detection System (VIDS), anti-theft protection measures shall be incorporated at both component and infrastructure levels. All camera poles, cabinets, and exposed elements shall be fitted with anti-climb mechanisms, such as galvanized steel spiked collars or tamper-proof housing boxes, to deter unauthorized access or vandalism. Cables and equipment enclosures shall be securely anchored and concealed wherever feasible. Lockable enclosures with reinforced hinges, internal bolt systems, and concealed locks shall be used to house sensitive electronics, including VIPUs and UPS modules. Motion detection intrusion sensors and door status monitoring shall be integrated into the cabinet security system, with alarms routed to the Traffic Management Center (TMC) in real time. The system shall log all access attempts, and physical keys or electronic access systems shall be controlled under the authority of the Engineer or designated agency.

7.33.3.12. Redundant Power Switching Module

The Redundant Power Switching Module shall ensure automatic failover between the primary power supply and the backup power system (UPS or solar), maintaining uninterrupted operation of all critical VIDS components. It shall monitor voltage levels in real time and seamlessly switch sources without affecting equipment performance or requiring manual intervention.

Technical Specifications:

Description	Value / Range
Switching Type	Automatic Transfer Switch (ATS) or Smart Redundant Power Controller
Number of Input Sources	Minimum 2 (Primary Grid + Secondary UPS or Solar)
Output Voltage Range	12V / 24V / 48V DC or 220V AC (configurable)
Switching Time	< 10 ms (for DC systems); < 30 ms (for AC systems)
Load Capacity	≥ 1000W total output (expandable)
Monitoring & Alarms	LED indicators + relay outputs for remote alerting
Communication Interface	RS-485 or Ethernet (optional) for integration with VIPU/TMC
Protection Features	Overload, reverse polarity, under-voltage, and over-temperature
Mounting	DIN rail or shelf mount inside an electronic cabinet
Operating Temperature	–20°C to +60°C
Compliance	IEC 60947-6-1, CE, RoHS

7.33.3.13. Motion Detection Camera for Intrusion Alarm

The motion detection camera shall be deployed to secure VIDS equipment cabinets and critical roadside assets against unauthorized access or tampering. It shall detect human presence or motion around restricted zones and generate real-time alarms to the VIPU and Traffic Management Center (TMC). The system shall operate reliably in both day and night conditions.

Technical Specifications:

Description	Value / Range
Image Sensor	1/2.9" CMOS, progressive scan
Resolution	Minimum 2 MP (1920 × 1080)
IR Capability	Built-in infrared illumination for ≥ 20 m range
Motion Detection Type	Pixel-based and AI-enhanced object detection
Detection Range	5 to 10 meters (adjustable sensitivity)
Field of View	Horizontal: ≥ 90°, Vertical: ≥ 50°
Operating Modes	Day/Night with IR-Cut Filter (ICR), auto-switching
Alarm Output	Dry contact relay or digital signal to VIPU/TMC
Video Compression	H.265 / H.264 / MJPEG
Communication Interface	RJ45 (Ethernet), optional Wi-Fi / RS-485
Power Supply	12V DC or PoE (IEEE 802.3af)
Power Consumption	≤ 7 W
Mounting	Surface-mount or pole-mount near entry points or cabinets
Protection Rating	IP66 outdoor-rated housing
Operating Temperature	−20°C to +55°C
Compliance	CE, FCC, RoHS, ONVIF compliant

7.33.3.14. Lightning Arrestor

The lightning arrestor shall provide surge protection to the entire VIDS infrastructure by safely diverting high-voltage surges from lightning strikes or power line disturbances to the ground. It shall be installed at critical power and communication line entry points near poles, cabinets, and communication nodes to protect all field equipment.

Technical Specifications:

Description	Value / Range
Type	Metal Oxide Varistor (MOV) or Spark Gap Type Lightning Arrestor
Nominal Discharge Voltage	230V AC / 48V DC (as per system voltage)
Maximum Surge Capacity	≥ 40 kA (8/20 μs waveform)
Discharge Voltage Level	Clamping voltage ≤ 900V (for 230V system)

Response Time	< 1 ns (nanosecond)
Installation Location	Power input panel, OFC entry point, and ground junction near equipment
Housing	Weatherproof (IP65 or higher), UV-stabilized thermoplastic or metal enclosure
Grounding Requirement	Must be bonded to earth rod (≤ 10 ohms resistance) as per IEEE 80
Operating Temperature	-40°C to $+70^{\circ}\text{C}$
Mounting	DIN rail or external pole/cabinet surface
Standards Compliance	IEC 61643-11, IEEE C62.41, BS EN 62305, CE, RoHS

7.33.3.15. Surge Protection and Grounding System

The surge protection and grounding system shall provide a comprehensive, integrated solution for shielding all VIDS field equipment, including cameras, VIPUs, power supplies, and communication lines, from electrical surges caused by lightning strikes, power fluctuations, and electromagnetic disturbances. The system shall combine a high-capacity lightning arrestor with a low-resistance grounding and bonding network to ensure safe dissipation of transient voltages and eliminate ground potential differences between components.

Technical Specifications:

Component	Specification
Surge Protection Device (SPD)	Metal Oxide Varistor (MOV) or Gas Discharge Tube (GDT) type
Nominal Discharge Voltage	230V AC or 48V DC (as per site requirements)
Maximum Surge Capacity	≥ 40 kA (8/20 μs waveform)
Response Time	< 1 ns
Installation Location	Power input panel, OFC/ISP entry points, and at device-side junctions
Clamping Voltage	$\leq 900\text{V}$ (for 230V)
Ground Resistance (System)	≤ 10 ohms (measured per IEEE Std 80 and BNBC)
Bonding Type	All metallic components (cabinets, poles, mounts) to be electrically bonded
Earthing Conductors	Copper/galvanized conductor (minimum 6 mm ² cross-section), green-yellow sheath
Earth Rods	Minimum 2.4 m copper-bonded steel rods (≥ 16 mm dia.) per site, one (01) or more as needed
Protection Housing	IP65-rated enclosure for SPD and earth termination blocks
Visual Indicators	SPD health/fault status LEDs
Maintenance Ports	External test clamps or maintenance access points
Standards Compliance	IEC 61643-11, IEEE Std 80, IEC 60364, NFPA 780, BNBC Electrical Chapter, CE

7.33.4. Software Requirements

The software system underpinning the Video Incident Detection System (VIDS) shall be responsible for real-time incident detection, edge analytics, alert generation, database synchronization, and centralized dashboard access. It shall use state-of-the-art computer vision techniques, artificial intelligence, and deep learning algorithms tuned to the dynamic and often unpredictable traffic conditions of Bangladesh. All modules shall be designed for high resilience, low-latency response, and seamless integration with central Traffic Management Center (TMC) applications.

The Video Incident Detection System (VIDS) software shall be built using a modular, scalable architecture. Each module shall serve a distinct role, from incident detection and classification to reporting and integration with the Traffic Management Center (TMC). The technical requirements specified here define the minimum performance, interoperability, and deployment standards to ensure operational effectiveness across diverse roadway environments in Bangladesh. The following tables outline the core software modules, their technical features, and functional specifications required for a robust and future-ready VIDS platform.

7.33.4.1. Core Functional Modules

Module	Functional Description
Video Analytics Engine	Performs object detection, tracking, trajectory analysis, and anomaly detection using deep learning models.
Incident Classification System	Categorizes incidents based on type and severity aligned with NIMS categories.
Alert Management System	Generates and manages real-time alerts; supports rule-based triggers and multi-channel notifications.
Data Management System	Handles local and central storage, synchronization, and indexing of video, logs, and analytics metadata.
User Interface Module	Web-based dashboard for real-time visualization, configuration, and historical analysis.
Security & Licensing Module	Manages encryption, user access, software licensing, and intellectual property ownership by RHD.

7.33.4.2. Technical Requirements

Category	Specification
AI Models Supported	YOLOv8, Mask R-CNN, DeepSORT, Transformer trackers (e.g., DeepSort, DCF, Re-identification, ByteTrack-S)
Object Types	Pedestrians, vehicles (motorcycles to HCVs), debris, smoke/fog, flame
Analytics Capabilities	Multi-object detection, trajectory-based anomaly detection, wrong-way, queue, speed drop, fire/fog detection

Detection Techniques	Dense/sparse optical flow, semantic segmentation, object re-ID, temporal ML (RNN/LSTM)
Event Handling	Detection in < 2 sec; pre/post event image snapshot buffering
Storage Modes	Continuous + event-triggered; 12+ hour edge buffer; indexed for retrieval
Synchronization	Auto re-sync via secure protocol; supports fallback caching during network failure
UI Platform	Browser-based, responsive, multilingual; supports incident maps and live feeds
Reporting	CSV/PDF reports, event timeline filters, downloadable images, and video clips
Interoperability	RESTful API, MQTT, JSON/XML; ONVIF compliance for video devices
Integration Interfaces	Compatible with TMC, ATMS, VMS, ANPR, EMS, and RWIS modules
Security Standards	TLS 1.3+, RBAC, encrypted firmware, OTA updates, system audit trails
Licensing & IPR	Licensed to RHD with full customization rights; source code to be handed over with IP retained by RHD

7.33.4.3. Functional Modules with Specifications

A. Analytics Engine

This module shall drive real-time video analytics through a combination of traditional image processing and modern deep learning approaches, allowing for highly accurate multi-lane incident detection.

Feature	Specification
Object Detection	Deep Learning-based (e.g., YOLOv8, Mask R-CNN)
Multi-Object Classification	Detects & classifies pedestrians, motorcycles, light/heavy vehicles, 14 types of RHD vehicle classification/ BRTA Classification
Behavior Analysis	Based on sparse/dense optical flow techniques, trajectory generation and prediction, and deviation analysis
Anomaly Detection	Real-time contextual anomaly detection using unsupervised ML models
Scene Understanding	Semantic segmentation for static hazards (e.g., objects on the road)
Lane Tracking	Detect wrong-way vehicles or drift via trajectory and flow patterns
Fog/Smoke Detection	Based on a dynamic histogram (based on pixel intensities) and background subtraction methods

Reference: [FHWA Video Analytics Guidelines, 2020]; [OpenCV/ONNX Computer Vision Frameworks]; [NVIDIA Deep Stream SDK]

B. Validation & Event Confirmation Module

To ensure reliability and avoid false positives, the VIDS software shall include an internal incident validation step. This module cross-verifies input from multiple frames, zones, or cameras before confirming an alert.

Feature	Specification
Temporal Validation	Verifies persistence of an event for a configurable duration (e.g., ≥ 3 seconds)
Multi-zone Confirmation	Requires detection in 2 or more detection zones or across frame timestamps
Confidence Thresholds	Incident confirmed only when confidence > pre-set limit (e.g., 85%)
Auto-Discard	Automatically discards non-persistent anomalies or camera noise

C. Data Storage & Synchronization

This module shall ensure reliable data recording and synchronization with central TMC servers, even under intermittent connectivity or power failure conditions.

Feature	Specification
Recording Modes	Continuous or event-triggered; metadata + video segments stored
Local Buffer	Minimum 12-hour buffer storage at field-level VIPUs (eMMC/SSD)
Auto Sync	Automatic data resynchronization to the TMC server once connectivity is restored
Data Integrity	Uses transaction logs and timestamped packet identifiers to avoid duplication/loss

Reference: [NEMA TS 2-2021 Synchronization Guidelines]; [ONVIF Profile G for Video Sync]

D. User Interface (Dashboard)

A web-based dashboard shall be provided for real-time monitoring, configuration, and historical querying. The dashboard must be hosted at the TMC and be accessible remotely with appropriate access credentials.

Feature	Specification
UI Type	Web-based, multilingual, responsive (tablet/desktop)
Visualization	Real-time video feed, map-based incident overlay, alert timeline
Search & Filter	Incident type, time range, severity, location-based filtering
Export Options	Downloadable CSV, PDF, or image/video snapshots for reporting
Alert Configuration	Rule-based configuration interface for defining detection zones, thresholds

E. Communication & API Integration

The VIDS platform shall be designed for interoperability with other ITS components such as ATMS, VMS, ANPR, and emergency systems.

Feature	Specification
API Type	RESTful APIs with JSON/XML payload
Protocol Support	HTTP/HTTPS, MQTT, SNMP, RTSP, ONVIF
System Integration	Compatible with RHD's central Traffic management Center (TMC) and regional command and control centers (RCCC)

F. Intellectual Property Rights (IPR)

To ensure sovereign control, long-term maintainability, and national customization of the VIDS platform, all intellectual property rights associated with the developed software shall be vested exclusively with the Roads and Highways Department (RHD). This includes ownership of all source code, trained AI/ML models, configuration files, user interfaces, and any related documentation developed under the contract.

IPR Element	Specification
Ownership	Full intellectual property rights, including copyright and source code, shall be transferred to RHD upon project completion.
Customizability	RHD shall have the unrestricted right to modify, expand, localize, or redeploy the software without vendor dependency.
Trained AI Models	All ML/DL models trained using Bangladeshi traffic data shall be treated as RHD intellectual property.
Documentation	Complete developer and system documentation shall be delivered alongside the source code for future in-house development.
Third-Party Components	Any third-party software used shall be limited to open-source or royalty-free licenses that do not restrict redistribution or modification.
Vendor Obligations	The vendor shall not reuse or redistribute the VIDS software, in whole or in part, for commercial or non-commercial use without written approval from RHD.

Note: This clause shall be enforceable through the primary contract agreement and shall supersede any licensing clauses proposed by the vendor unless otherwise approved by RHD.

G. Software Maintenance and Licensing Support

The VIDS software shall be delivered as a perpetual, site-licensed product with all customization and deployment rights retained by the Roads and Highways Department (RHD). Ongoing operational maintenance, system support, and warranty shall be included in the licensing agreement.

Area	Specification
Licensing Model	Perpetual license for RHD with full source code and customization rights
Support Coverage	24/7 technical support via email, phone, or portal
Failure Response SLA	Vendor must respond to critical system failures within 4 hours; resolution within 24 hours
Maintenance Period	Minimum 5 years post-deployment support included in base contract
Update Policy	Free updates for patches, security, and performance improvements for the licensed period

Monitoring	Vendor shall provide remote diagnostics and real-time performance monitoring tools
Issue Logging	Centralized incident ticketing system for fault tracking and resolution auditability
Documentation	Complete user manuals, developer guides, and maintenance logs shall be provided

H. Reporting and Data Export

The VIDS software shall include an integrated reporting module for operational oversight, incident analytics, and regulatory compliance. It shall support scheduled and on-demand generation of structured reports for system administrators, engineers, and traffic authorities.

Feature	Specification
Report Types	Daily, weekly, monthly incident summaries; event-wise breakdown reports; uptime/downtime logs; false alert rates
Content	Incident metadata (type, location, time, severity), video snapshots, alert timelines, system health logs
Formats Supported	CSV, Excel, PDF, and JSON/XML export for machine-readable use
Customization	Template-based filters for location, time period, severity, or detection type
Automated Scheduling	Reports can be auto-generated and emailed to designated users based on a predefined schedule
Dashboard Export	Real-time map view and video event timelines exportable as snapshots or videos

I. Integration with Traffic Management Center (TMC)

The VIDS software platform shall be hosted within the central TMC application as a dedicated module. It shall interface with:

- Local site Network Video Recorders (NVRs) for real-time video and storage
- TMC dashboard for central monitoring
- Other ITS modules for coordinated response (e.g., VMS for alerts, EMS for emergency dispatch)

Data may be relayed via local or regional command centers with edge-NVRs acting as intermediaries, ensuring near-real-time redundancy and alert routing.

7.33.4.4. Accuracy and Performance Requirements

The detection performance of VIDS software shall meet the following minimum standards:

Incident Type	Detection Accuracy	Time to Detect
Stopped Vehicle	≥ 95%	≤ 10 seconds
Queue Formation	≥ 99.5%	≤ 5 seconds
Wrong-Way Driving	≥ 95%	≤ 5 seconds

Pedestrian / Jaywalking / Chicken Run	≥ 90%	≤ 5 seconds
Object Drop / Fallen Material	≥ 90%	≤ 5 seconds
Smoke / Fog Detection	≥ 85%	≤ 10 seconds
Multi-Vehicle Collision/ Crash	≥ 95%	≤ 5 seconds
Fire / Flame	≥ 90%	≤ 5 seconds
Vehicle Stalled in Active Lane	≥ 95%	≤ 5 seconds
Slow-moving/Non-motorized Vehicle on Fast Lane/Motor Lane	≥ 95%	≤ 5 seconds
Speed Drop / Sudden Deceleration	≥ 90%	≤ 2 seconds
Environmental Obstruction (Dust, Smog)	≥ 85%	≤ 10 seconds
Crowd or Human Blockage on Roadway	≥ 90%	≤ 5 seconds
Reverse Direction Across Lanes	≥ 95%	≤ 5 seconds
Hazardous Spill	≥ 95%	≤ 10 seconds
Overtaken Truck / Large Vehicle	≥ 95%	≤ 5 seconds
Video Signal Loss / Camera Tampering / Vandalizing	Auto Alarm Triggered	Instantaneous
Video Quality Degradation/ Error/Communication Problem	AI-Assisted Detection	≤ 3 seconds

Note: All validations must be supported by test data logs, simulation outcomes, and field acceptance trials as part of commissioning.

7.33.4.5. Additional Requirements

The software and associated backend components shall provide the following additional capabilities:

Requirement Category	Specification
Video Streaming and Recording	TMC shall be able to view and record real-time video streams; authorized ATMS terminals shall have live access.
Camera Stability Compensation	LPU shall auto-compensate for camera vibration or displacement due to wind, traffic, or pole sway.
Speed Measurement Range	System shall reliably measure vehicle speed between 0–150 km/h across all covered lanes.
Remote Configuration	All VIPUs and detection zones shall support remote configuration and firmware updates via GUI/drop-down tools.
Data Backup & Resilience	Local LPU storage shall buffer a minimum of 300 (or as decided by the Engineer) alarm events with both pre- and post-incident image sequences.
Network Configuration Interface	Software GUI shall display full system topology with interactive card/module selection and status monitoring.
Alarms for System Health	Shall automatically detect and notify: (a) poor video quality, (b) no signal, (c) communication failure.
Historical Data Access	TMC operators shall access archived incident records and video logs via a secure search interface.
Auto-Cleaning & Syncing	Local LPU shall auto-clean after successful data sync with the central server.

Conditional Alarm Suppression	Ability to disable specific alarms under contextual traffic patterns (e.g., disable the stopped vehicle alarm during a queue).

7.33.5. Installation of Supporting Structures and Appurtenances

For VIDS installation requiring supporting infrastructure such as poles, cantilevers, gantries, foundations, power and communication systems, installation practices, grounding, lightning protection, and cable works, the general specifications developed for Axle Load Control Stations (ALCS) outlined in Sections 7.38.3.2 through 7.38.3.8 of this Specification, shall be applicable where relevant and technically appropriate.

The Contractor shall follow the technical requirements, standards, materials, workmanship, installation methods, testing procedures, and safety provisions specified in the referenced sections, except where those provisions are explicitly specific to Axle Load Control Stations, such as equipment configuration, HS-WIM/MS-WIM/LS-WIM systems. However, Special attention must be given to supporting structures to withstand local wind loads, vibrations, and environmental conditions to maintain the desired accuracy of the system.

In case of ambiguity or overlap, the Engineer shall provide clarification on the applicability of any referenced requirement to the VIDS scope.

7.33.6. Testing and Commissioning

The testing and commissioning of the Video Incident Detection System (VIDS) shall be carried out systematically in phases to verify the functionality, performance, integration, and compliance of all hardware and software components before system handover. All testing procedures shall be approved by the Engineer and conducted in the presence of RHD representatives.

7.33.6.1. Factory Acceptance Test (FAT)

The Contractor shall perform FAT for major components (e.g., Video Image Processing Units, industrial switches, UPS, software platform) before dispatch to the site. The FAT shall include:

- Verification of hardware compliance with technical specifications.
- Software functionality tests (e.g., incident detection, alarms, dashboard).
- Network connectivity and protocol compliance (ONVIF, MQTT, TCP/IP).
- Video analytics demonstration for all incident types using sample clips.
- Endurance test (minimum 48 hours continuous run).
- System response to simulated input and failure conditions.

7.33.6.2. Site Acceptance Test (SAT)

After installation, SAT shall be conducted for all field locations. This shall include:

- Physical installation verification (height, angle, field of view, protection systems).
- Power supply test including grid, UPS, and solar inputs.
- Connectivity to TMC, RCCC, and NVR.
- Performance test of incident detection accuracy per Table 7.33.4.4.
- Verification of flashing lights, alarms, and hooter activation.
- User Interface validation for live streaming, alerts, map view, and analytics.
- Remote access and configuration demonstration.
- Data integrity test (buffering, storage, synchronization).
- Redundancy and failover test for power and communication.

7.33.6.3. Integrated System Test

The integrated system shall be tested in live traffic conditions to validate:

- Real-time detection and alarm of all defined incidents.
- Communication flow from VIPU to TMC and back.
- Interfacing with other ITS systems (VMS, ANPR, RWIS).
- Time-to-detect and alert response benchmarking.
- Automated report generation and system logs verification.

7.33.6.4. Provisional Acceptance Test (PAT)

Following a successful SAT, a 30-day Provisional Acceptance Test shall be conducted to verify:

- Continuous 24/7 operation of the system under live conditions.
- No critical alarms, repeated errors, or failure events.
- Incident detection performance $\geq$ specified thresholds.
- Auto recovery from simulated failures (power/network).
- Successful remote health monitoring from TMC.

7.33.6.5. Final Acceptance and Handover

Final Acceptance will be granted after:

- Satisfactory PAT results.
- Submission of all documentation (as-built drawings, manuals, software licenses, source code).
- On-site training completion for RHD staff.

- Delivery of spare parts and tools as per BOQ.
- Sign-off on system performance report and test results.

7.33.7. Measurement

The measurement for the Video Incident Detection System (VIDS) shall encompass the complete scope of activities required to deliver a fully functional, automated, and intelligent incident detection solution across designated highway segments and control centers. The system shall include the design, supply, installation, calibration, integration, configuration, testing, commissioning, licensing, and training associated with the VIDS solution. The Contractor shall be responsible for delivering a complete, fully interoperable, and TMC-integrated incident detection solution compliant with Roads and Highways Department (RHD) standards, incident management protocols, and ITS interoperability guidelines.

Each VIDS installation site shall be measured based on the number of deployed detection units and functional incident detection coverage zones. Measurement shall cover the complete set of video detection cameras with IR filters and sunshields, AI-enabled video processing units, flashing warning lights, network switches, enclosures, UPS systems, solar lighting, and audible alarms, along with all associated mounting hardware, communication links, structured cabling, and electrical protection systems.

The Video Camera subsystem shall be measured per camera unit, inclusive of pole/gantry mounting, varifocal lens, integrated IR support, and optional self-cleaning modules. The Local Video Image Processing Units (VIPUs) shall be measured per device, inclusive of all required edge-processing capabilities, AI accelerator modules, multi-lane video stream inputs, alarm I/O, and OTA software integration with TMC.

The system shall include network components and switching infrastructure with redundant design, and these shall be measured per unit installed. Each field cabinet (with integrated grounding, cooling, and power distribution), UPS system (with minimum 4-hour backup), hooter alarms, and warning lights shall be measured individually.

The VIDS software platform, including its edge-based analytics engine, real-time dashboard, reporting module, synchronization logic, validation engine, and system security functions, shall be measured as a system-wide implementation. This shall include installation at the TMC and/or regional command centers, full data pipeline integration, reporting modules, and API endpoints for interoperability with ANPR, RWIS, VMS, and other ITS elements. Measurement of the software component shall be on a per-system basis, conditional on successful deployment, configuration, and test validation across all integrated field sites.

All components shall be measured only after installation, functional verification, and successful operation of real-time detection for all specified incident types, verified through on-site testing and commissioning logs.

Measurement shall also cover the supply, termination, and testing of OFC and ISP communication links between field devices and the Traffic Management Center (TMC), including all required enclosures, fiber patch panels, splicing trays, and diagnostic tools.

All software developed and implemented under this contract shall be treated as the exclusive intellectual property of the Roads and Highways Department (RHD). This includes source code, AI models, configuration files, and system logic. Measurement of software shall only be made after submission of complete source code (where applicable), license files, customization tools, administrative dashboards, and system documentation to the RHD.

The system shall support a minimum detection accuracy of 95% (depending on the incident type) and minimum detection latency thresholds as defined in Section 7.33.4.4. These performance benchmarks shall be tested and validated through trial runs using standard traffic scenarios during commissioning. System measurement shall not be deemed complete until such performance requirements are met and verified by the Engineer.

Testing, commissioning, and training shall be measured as a lump sum per VIDS installation package and shall include:

- Factory Acceptance Testing (FAT)
- Site Acceptance Testing (SAT)
- System Commissioning and Operational Testing
- Data synchronization and reporting trials
- End-of-Warranty System Review
- Hands-on training for RHD operators, MIS staff, and field engineers

Training shall include both classroom instruction and field demonstration, covering the software interface, troubleshooting, data review, alert handling, and system maintenance practices. Submission of SOPs, visual aids, training manuals, and operational logs shall be a prerequisite for this milestone.

All field installations, hardware enclosures, communication nodes, and software platforms shall be considered as part of an integrated system. They must be fully functional, interoperable, and integrated adequately before measurement will be accepted for any item. Measurement of partial or non-operational units, or components not integrated with the TMC platform, shall not be accepted.

Measurement of all related civil, trenching, pole foundation, earthing, and ducting works shall be made separately under respective BOQ items; however, the VIDS system shall not be considered complete without its functional availability.

Final measurement and payment shall only be approved upon successful completion of the whole system deployment, submission of as-built documentation, performance logs, configuration backups, signed testing reports, software licensing handover, and formal certification of system acceptance by the Engineer.

7.33.8. Payment

Payment for the Video Incident Detection System (VIDS) shall be made based on the full delivery of a complete, fully integrated, and operational system along designated highway corridors or critical locations, as approved by the Engineer. The payment items listed herein cover both hardware and software components, analytics systems, data integration elements, and their associated installation, configuration, testing, and commissioning works.

The following pay items may be amended, extended, or optimized depending on evolving ITS standards, site-specific functional requirements, or regulatory changes. Related civil and structural works, including foundations, poles, cable ducts, earthing, trenching, and structural supports, shall be measured and paid under separate sections of the RHD Technical Specification.

Pay items shall be subject to further breakdown and disaggregation as per actual implementation requirements and at the discretion of the Engineer. This may include adjustments in units, system configurations, deployment phasing, or integration modalities depending on site-specific conditions, system evolution, or stakeholder coordination protocols.

Pay Item No.	Description	Unit
7.33.1	Supply, installation, testing, and commissioning of high-resolution IP camera with IR filter, IP67 enclosure, integrated analytics capability, varifocal lens, and ONVIF compliance for VIDS	Number
7.33.2	Provision of Video Image Processing Unit (VIPU) with integrated GPU, edge-based AI inference capability, multi-channel HD video support, and real-time analytics engine with deep learning framework	Number
7.33.4	Supply and installation of self-cleaning or maintenance-assist camera system, including wiper, nozzle, or hydrophobic lens coatings; remotely triggered via TMC	Number

7.33.5	Supply, installation, and integration of AI-based VIDS Software Platform, including object detection, behavior analysis, anomaly detection, queue/speed/fog/fire analytics, and incident classification as per NIMS	Per Site
7.33.6	Supply and configuration of Data Storage & Sync Module, including event-based video recording, 12-hour edge buffer, auto-sync with TMC, and timestamp-based integrity check	Per Site
7.33.7	Supply and commissioning of VIDS Dashboard for central TMC access with multilingual web interface, alert log, video playback, and report export module	Number
7.33.8	Set up and configuration of RESTful API suite with ONVIF/RTSP/MQTT/JSON integration protocols for ATMS/VMS/ANPR/RWIS interoperability	Number
7.33.9	Supply and commissioning of IP66-rated Outdoor Electronic Cabinet with DIN rails, fan ventilation, AC-DC power supply, alarm module, temperature sensor, and anti-theft enclosure	Number
7.33.10	Supply, installation, and configuration of a multi-port Industrial PoE Switch with dual SFP uplinks, IP30 rating, redundant power supply, and RSTP/QoS support	Number
7.33.11	Provision and configuration of online UPS ($\geq$ 4-hour backup, IP54), with VRLA or Li-ion batteries for continuous power to VIPU and surveillance units	Number
7.33.12	Provision and installation of multi-core Armored Optical Fiber Cable, including trenching, splicing, ducting, and termination with LIUs at both field and TMC ends	Meter
7.33.13	Supply and installation of Anti-Theft Intrusion Detection Camera/System with motion detection, intrusion alert, and night surveillance (IR-enabled)	Number
7.33.14	Supply and configuration of Redundant Power Switching Unit (Auto Transfer Switch) for seamless UPS/grid/solar source switching	Number
7.33.15	Provision of Lightning Arrestor with $\geq 40\text{kA}$ discharge capacity, grounded to <10 ohms, with surge protection panel and IEC 61643 compliance	Number
7.33.16	Supply, testing, and commissioning of Surge Protection & Earthing System for camera poles, cabinets, and electronics, including earth pit and copper-bonded rods	Per Site
7.33.17	Supply and commissioning of AI-integrated incident detection validation engine, including multi-frame confirmation, confidence thresholding, and false positive filtering	Per Site
7.33.18	Installation, configuration, and deployment of VIDS report generation and analytics system, including pre-scheduled PDF/CSV generation, timeline filters, and email auto-scheduler	Per Site
7.33.19	Integration of VIDS software into TMC application and RCC dashboards, including NVR feed linkage, dashboard visualization, and alert relay via command center	Lump Sum
7.33.20	Final Testing, Commissioning, and Field Acceptance Trials of the complete VIDS platform, including system tuning, AI model calibration, and alert verification	Lump Sum

7.33.21	Operation and Maintenance of the deployed VIDS platform, including preventive maintenance, software updates, system health monitoring, and post-deployment support for x years	Per Year
7.33.22	Training of RHD engineers, MIS staff, and system administrators for system operation, configuration, and diagnostics, including manuals and SOP delivery	Lump Sum
7.33.23	Training of field personnel, monitoring officers, and maintenance crews on camera care, basic fault handling, and event confirmation SOPs	Lump Sum

7.34. Automated Speed Enforcement System (ASES) integrated with Security Surveillance (SS)

7.34.1. General

This work shall consist of the design, supply, installation, integration, testing, and commissioning of an Automated Speed Enforcement System (ASES) with integrated Security Surveillance (SS) capabilities. The system shall detect, capture, and document speed violations automatically through Doppler radar-based speed detection (commonly integrated with LPR bullet cameras), LIDAR-based speed measurement, or video-based speed measurement technologies, while concurrently recognizing the number plate of the violating vehicle using Automatic Number Plate Recognition (ANPR) techniques, and providing continuous CCTV monitoring for enhanced situational awareness and road user behavior monitoring. The system shall be based on proven, reliable, and IP-based modular technology, and shall be fully integrated with the Traffic Management Centre (TMC) or other monitoring platforms approved by the Engineer. The ASES-SS system shall serve both law enforcement and safety monitoring purposes and shall be scalable to accommodate future ITS expansion, in accordance with the Bangladesh National ITS Master Plan for RHD.

7.34.2. Generic Requirements

The objective is to automatically detect speeding violations, capture associated vehicle data including license plate, speed, date, time, and location, and provide high-resolution video monitoring coverage for road safety, traffic enforcement, and infrastructure security.

The Automated Speed Enforcement System (ASES) shall be deployed at key road segments where speeding has been identified as a primary risk factor. Site selection shall be based on crash history, observed or modelled vehicle speeds, roadway geometry, pedestrian exposure, and traffic engineering judgement.

Typical application locations for speed detection include:

- High-speed corridors and rural highways where over-speeding contributes significantly to fatal and serious injury crashes.
- Steep downgrades, horizontal curves, and transition zones, where maintaining lower speeds is critical for vehicle control.
- Crash-prone segments or blackspots, particularly those identified through speed-related collision analysis or road safety audit findings.
- Entry and exit zones of toll plazas, interchanges, and bridges, where speed transitions and merging behavior require regulated speed control.
- School zones, pedestrian crossings, and densely populated urban areas, where reduced speed limits are in effect to protect vulnerable road users.

All speed detection locations shall be selected in coordination with RHD's Road Design and Safety Circle and shall be integrated with the nearest Traffic Management Center (TMC) for optimal monitoring, data archiving, and violation (ticket) processing.

7.34.2. Technical and Functional Requirements

7.34.2.1. Definition of Speed Violation

A **speed violation**, for the Automated Speed Enforcement System (ASES) deployed under the Intelligent Transport System (ITS) framework of the Roads and Highways Department (RHD) of Bangladesh, is defined as:

“An incident where a vehicle's recorded speed exceeds the legally posted speed limit at a designated monitoring location. Violations shall be detected using certified technologies such as Doppler radar, LIDAR, or video-based analytics, integrated with Automatic Number Plate Recognition (ANPR) to identify the offending vehicle concurrently.”

Each violation event must include the following data:

- Measured vehicle speed and posted speed limit
- Violation margin (absolute or percentage)
- Time, date, and GPS-based location
- Vehicle class

- Vehicle color
- High-resolution image(s) of the vehicle and number plate
- Camera ID and lane assignment

Speed violations shall only be recognized when the recorded speed exceeds the enforcement thresholds defined by contemporary national traffic laws, such as the Bangladesh Road Transport Authority Act and/ Bangladesh Road Transport Rules, or RHD enforcement protocols. These thresholds may include legally permitted tolerances above the posted speed limit to account for calibration margins or policy-based enforcement criteria (Such as for overtaking lane, emergency lane/ vehicles, etc.). Routine speed variations within acceptable tolerance ranges, or those associated with authorized emergency or enforcement vehicles, shall not be flagged as violations.

7.34.2.2. ASES-SS Functionalities

Vehicle Classification and Identification

The system shall automatically classify vehicles by category (e.g., motorcycle, car, light commercial vehicle, bus, truck, trailer) using image analytics, edge computing, and AI-based algorithms. The classification shall be based on vehicle size, shape, and visual features such as color and make. Each identified vehicle shall be assigned to 'vehicle type' metadata, including:

- Vehicle class as per RHD/BRTA Classification
- Body color
- Presence or absence of number plates
- Vehicle registration number
- Vehicle direction
- Brand and model (where feasible)

The built-in/external local processing unit (LPU) with ANPR camera/ATCC system shall support classification accuracy of $\geq 95\%$ (Level A) under day/night and all-weather conditions.

Over-speeding Detection

The system shall detect and record vehicles exceeding predefined speed thresholds (legal speed limit) using one or more of the following technologies: Doppler radar-based detection integrated with ANPR or enforcement cameras, or LIDAR-based speed measurement where deployed, or video analytics-based speed estimation utilizing frame-to-frame object tracking techniques. The system shall automatically correlate each speed violation with the following metadata:

- Measured vehicle speed and applicable posted speed limit
- Violation margin (in km/h or as a percentage above the legal limit)
- Date and time stamp of the event
- Geolocation (GPS coordinates) of the detection point
- Traffic lane and travel direction
- Vehicle registration number/license plate number (both in Bangla and English) identified by an ANPR device
- Vehicle information as acquired in ‘vehicle type’ metadata

Each violation shall be captured using high-resolution imaging systems capable of producing evidentiary-quality visuals in all lighting and weather conditions. Evidence packages shall include:

- Full vehicle image
- Cropped number plate view
- Short video (3~5s) of the violation incident
- Overlay of speed information and violation data

These data shall be securely transmitted in real-time to the Traffic Management Centre (TMC) or designated enforcement platform for validation, automated ticket generation, archiving, and legal processing. The system shall support secure integration with national vehicle registration databases (e.g., BRTA vehicle registration database) for verification of ownership, classification, and compliance.

Fugitive Vehicle Identification

The system shall be capable of identifying vehicles flagged on watchlists (e.g., stolen vehicles, blacklisted number plates, or suspect vehicles involved in crimes or traffic violations). This shall be done by matching real-time ANPR results against a centralized Black/White list database maintained by the Law enforcement agencies/ National Traffic Database. Apart from the primary requirement to be placed in over-speed-prone or vulnerable locations (as mentioned in Generic Requirements), the deployment of the ASES-SS shall also consider major or potential escape routes that can be used by fugitive vehicles within the surveillance network, ensuring comprehensive enforcement coverage. Upon detection of a fugitive vehicle, the system shall automatically generate an alert containing the ANPR log, full vehicle image, GPS location, and timestamp. This alert shall be securely and instantly transmitted to the designated law enforcement agency through the integrated ITS communication network for immediate action.

Vicinity Surveillance

As an added feature of the ASES-SS system, real-time wide-area situational surveillance shall be provided through integrated PTZ cameras. Along with the main corridor, these cameras shall be deployed to monitor intersections, service roads, highway shoulders, and other critical locations within a radius of up to 1000 meters of the surveillance network. The system shall support manual tracking of moving objects, enabling real-time verification of detected violations and monitoring of suspicious activities such as illegal stopping, intrusion, or vandalism. In addition to traffic monitoring, the surveillance capability shall also support remote oversight of ASES-SS devices themselves, facilitating operational status checks, tamper detection, and maintenance verification. Surveillance footage shall be transmitted to the Traffic Management Centre (TMC) and securely stored for enforcement and review purposes.

Traffic Flow Measurement

The ASES-SS system shall be capable of estimating real-time traffic flow parameters to support effective traffic management and incident response. These parameters shall include vehicle counts per lane and per time interval, occupancy rates, average speeds, direction-wise flow volumes, and traffic density across defined sections of the roadway. Measurement at highway segments with major changes in flow parameters, the system shall be strategically installed at locations where significant volumes of traffic merge into or diverge from the monitored network, such as interchanges, ramps, junctions, etc., connecting major regional/national highways. This strategic placement shall not only ensure comprehensive monitoring of daily traffic flow and vehicle movements but also enhance the system's effectiveness in covering major escape routes, thereby improving the detection and tracking of fugitive vehicles. The processed data shall be transmitted to the Traffic Management Centre (TMC) for record, visualization, statistical analysis, and integration into broader ITS services, including congestion management, Variable Message Sign (VMS) advisories, or other media.

7.34.2.3. System requirements

The Automated Speed Enforcement System with Surveillance Support (ASES-SS) shall provide an integrated, IP-based surveillance and enforcement solution. The system shall be designed to perform the following core functions and meet the following requirements:

A. System Architecture and Video Processing

- The system shall operate over an **open-standard, IP-centric architecture** to support high-speed data transmission, distributed edge processing, and seamless integration with other ITS subsystems, **including ANPR, ATCC, PTZ, and AI-based video analytics.**
- **It shall enable real-time online display of live video feeds and enforcement events at the Traffic Management Centre (TMC), National registration databases (e.g., BRTA) for vehicle validation, Law enforcement watchlists, and alert systems** for fugitive identification accessible through **high-definition displays** or equivalent interfaces.
- The system shall ingest and process live streams from multiple camera types, including **ANPR, PTZ, and fixed bullet cameras**, deployed along the corridor, interchanges, ramps, and service roads.
- Video feeds shall be displayed simultaneously across **control workstations** and **archived** in secure, searchable databases for review, evidence generation, and performance analysis.

B. Video Format and Transmission

- **Encoders and cameras** shall support **H.264 (MPEG-4 AVC)** compliant video compression (ISO/IEC 14496-10), ensuring interoperability across different manufacturers.
- Supported video resolution shall range from **CIF to D1 or higher**, with **frame rates configurable up to 60 FPS per camera.**
- In case of analog legacy deployments, **hardware encoders** shall convert analog signals to digital format, supporting **dual H.264 video streams at ≥ 30 FPS** per channel with a latency ≤ 200 milliseconds
- Cameras shall support **PoE** or be connected through **CAT 6 or fiber optic cables** to Layer 2/3 network switches per system layout.
- All networked components shall support **unicast/multicast streaming** and provide configurable **QoS and redundancy** options to ensure continuous availability.

C. Camera System Requirements

- PTZ cameras shall support **360° continuous pan**, **2°–92° tilt**, and a minimum **35× optical zoom**, with **pre-programmed** tour modes for automatic surveillance sweeps across predefined points.
- All surveillance cameras must support day/night capability, IR-cut filters, minimum low-light sensitivity of 0.02 lux, and dynamic light adaptation of at least 10,000:1.
- All cameras shall feature flat-glass windows with internal heating elements to maintain optimal optical clarity in humid or rainy conditions and prevent fogging or condensation.
- Camera housings shall be IP66-rated or higher, weather-sealed, and corrosion-resistant to withstand harsh environmental conditions.
- Camera poles and mounting structures shall be wind-resistant up to **200 km/h**, and vibration-dampened to ensure image clarity under adverse conditions.

D. Statistical Reporting and Performance Dashboard

- The system shall automatically generate **real-time and historical analytics**, accessible via a **web-based dashboard**, and exportable as PDF/CSV reports.
- Reports shall include:
 - Violations by class, time, and location
 - Peak violation periods and offender patterns
 - Speed profiles (average vs. peak)
 - Compliance trends before and after enforcement
 - Geographic heatmaps of violation clusters
- These analytics shall support policy refinement, enforcement resource allocation, and public awareness strategies.

E. Event Packaging

The system shall compile all relevant violation and classification data into a **digitally signed, uniquely identified violation package**. This package shall be generated automatically by the Local Processing Unit (LPU) or integrated enforcement server and transmitted in real time to the Traffic Management Centre (TMC) or designated backend platform. The event package shall include:

A. Speed Violation Metadata

- Measured vehicle speed
- Applicable posted speed limit
- Violation margin (in km/h or as a percentage over limit)
- Date and time of the event
- Geolocation (GPS coordinates) of the detection point
- Traffic lane number and travel direction
- Overspeed detection method used (e.g., radar, LIDAR, video tracking)

B. Vehicle Identification and Classification Data

- License plate number identified by ANPR (Bangla and English character strings)
- Presence or absence of a visible number plate
- Vehicle class as per RHD/BRTA classification
- Body color
- Vehicle make and model (where identifiable)
- Vehicle movement direction (entry/exit, inbound/outbound, etc.)
- Classification confidence level (e.g., $\geq 95\%$ Level A accuracy flag)

C. Digital Evidence Components

- Full-frame image of the violating vehicle
- Cropped number plate image
- Short video clip (3–5 seconds) of the violation event (frame-stamped)
- Overlay of speed reading, location, timestamp, and violation code on images/video
- Camera ID and location ID
- Environmental conditions (e.g., night/day, weather conditions if sensor data available)

D. Security and Compliance Layer

- Digital signature and unique violation package ID
- Timestamp of packaging and transmission
- Encryption of data prior to transmission to TMC
- Hash value or checksum for tamper detection
- System health status flag (camera operational, ANPR sync OK, etc.)

E. Optional Alert Flags (If Applicable)

- **Fugitive Vehicle Flag:** If matched with the law enforcement database
- **Device Tamper Alert:** If a violation event coincides with any system tampering
- **Vicinity Event Link:** If PTZ surveillance was activated during/after the event
- **Incident Correlation Flag:** If the event overlaps with a traffic anomaly or congestion surge

This event package shall be **archived** in a secure, searchable enforcement database and made available to integrated systems for **ticket generation, statistical reporting, and legal processing**. The system shall allow **traceability and auditability** of each event package throughout its lifecycle, from roadside capture to legal enforcement.

7.34.2.4. System Integration

The **Automated Speed Enforcement System integrated with Surveillance System (ASES-SS)** shall support the core principles of the **Incident Command System (ICS)**, which includes standardized communication protocols, unified multi-agency command, real-time incident documentation, and operational coordination. ASES-SS shall be fully interoperable with Traffic Management Centers (TMCs) and shall generate structured incident data to support all relevant stages of the incident management lifecycle, from detection to recovery and termination.

The ASES system shall provide a **fully automated and secure workflow** for processing speed violations from detection to archival:

- **Detection:** Vehicles exceeding the posted speed limit are detected in real-time using calibrated Doppler radar, LIDAR, or video-based analytics. Each event is automatically timestamped and linked to its GPS location.
- **Capture:** High-resolution images of the violating vehicle are captured along with automatic number plate recognition (ANPR) to extract the vehicle's license plate string.
- **Site Display:** A digital Speed Display Unit (SDU) shall display measured vehicle speed at the site. Green numerals shall indicate compliance, while red numerals shall alert overspeeding drivers, serving as a proactive deterrent.
- **Event Packaging:** The system shall compile all data into a digitally signed, uniquely identified speed violation, vehicle identification and classification, digital evidence components, security and compliance layer, and alert flag packages.
- **Encryption and Transmission:** Violation packages shall be encrypted and securely transmitted to the Traffic Management Center (TMC) or authorized enforcement back-end system for further processing.
- **Validation:** Each violation is validated through automated checks for image quality, number plate legibility, and threshold compliance. A manual verification interface shall be available at the TMC for disputed or borderline cases.
- **Statistical Demonstration:** The system shall provide configurable dashboards and exportable reports detailing violation frequency, location-based trends, peak periods, top repeat violators, and enforcement effectiveness. Data shall be filterable by date, zone, or lane.
- **Ticket Generation:** Once validated, violation records shall be linked with vehicle registration databases to generate digital violation tickets, including all required metadata and evidence images. These can be printed or sent electronically to the vehicle owner, subject to enforcement agency protocols.
- **Notification:** The system shall optionally support automated delivery of violation alerts to designated agencies (e.g., Traffic Police, BRTA) and registered vehicle owners via integrated SMS/email systems.
- **Storage and Archiving:** All validated violation records, images, and metadata shall be archived in a secure, searchable database for a minimum of 6 to 12 months, in accordance with RHD's data retention and privacy policies.

Table 7.34-2 below summarizes how ASES-SS supports each stage of speed enforcement and surveillance function.

Table 7.34-2: ASES-SS-Supported Enforcement Functions and Stages (adapted from (Gordon, R., 2015)).

ASES-SS Enforcement Stage	Detection	Capture & Packaging	Validation	Response/ Notification	Archiving & Reporting
Detect vehicle over-speeding using Doppler/LIDAR/Video	√				

Capture a high-resolution vehicle image and ANPR plate		√			
Display vehicle speed at roadside (Speed Display Unit)	√				
Compile violation package (speed, time, GPS, plate, etc.)		√			
Digitally sign, encrypt, and transmit violation data		√			
Perform automated validation (image quality, plate, etc.)			√		
Enable manual review for edge cases at TMC			√		
Link validated events with vehicle registration data			√	√	
Generate a violation ticket (digital or print)				√	
Notify law enforcement or vehicle owner (App/SMS/email)				√	
Archive validated violations and metadata					√
Provide dashboards and statistical violation reports					√

7.34.2.5. Optical and Placement Requirements for ASES-SS Cameras

Refer to section 7.33.2.6

7.34.3. Hardware Requirements

The following sub-components have been selected to meet the demanding environmental and operational conditions of national highways while ensuring seamless integration, continuous enforcement functionality, and long-term system reliability of the ASES-SS:

1. **Speed Detection Unit** –Microwave-based radar sensor module designed for accurate multi-lane vehicle speed measurement. Optionally, AI-based processing may be integrated for enhanced tracking and lane-specific classification.
2. **ANPR & Violation Detection Camera** – High-resolution imaging system with integrated infrared (IR) illumination for license plate recognition and violation evidence capture across all weather and lighting conditions. The system shall incorporate advanced Optical Character Recognition (OCR) algorithms for accurate alphanumeric decoding of number plates, including support for regional plate formats and multiple languages. Designed for day/night operation with real-time metadata tagging (e.g., time, location, lane).
3. **PTZ Surveillance Camera** – Pan-Tilt-Zoom camera for real-time visual monitoring, vicinity surveillance, and manual or automated target tracking.

4. **Speed Display Unit (SDU)** – LED-based numeric display to show real-time vehicle speed in compliance or overspeed format for driver awareness and deterrence.
5. **Local Processing Unit (LPU)** – On-site edge analytics controller for enforcement logic, data packaging, and device coordination.
6. **Industrial Network Switch** – Managed Ethernet switch with PoE and redundancy to facilitate stable communication between field components and the TMC.
7. **Electronic Equipment Cabinets** – Outdoor-rated enclosures to securely house LPUs, UPS, network switches, and associated control hardware.
8. **Uninterruptible Power Supply (UPS)** – A Backup power system for ensuring continuous operation during a grid failure for a minimum of 4 hours.
9. **Hooter Alarm Unit** – Audible alarm system activated upon critical enforcement events such as wrong-way movement or tampering.
10. **Power Supply System** – Structured power delivery with protective breakers, surge shielding, and integration of ATS for seamless switching between primary and backup power sources.
11. **OFC / Cellular Communication Module** – Optical fiber or 4G/LTE-based communication unit to enable high-speed data transfer to the central Traffic Management Centre.
12. **Anti-Theft and Intrusion System** – Tamper and intrusion monitoring devices to protect critical field equipment from unauthorized access.
13. **Redundant Power Switching Unit** – Automated module to switch between utility grid, UPS, and optional solar inputs to maintain uninterrupted operation.
14. **Motion Detection Camera for Intrusion Alarm** – Surveillance to detect unauthorized activity around sensitive field assets.
15. **Lightning Arrestor** – Surge diversion device to prevent equipment damage from lightning strikes.
16. **Surge Protection and Grounding System** – Integrated SPD and grounding network to shield equipment from electrical surges and ensure safety

7.34.3.1. ANPR & Violation Detection Camera

The ANPR & Violation Detection Camera shall provide high-speed vehicle image capture, automatic number plate recognition, and metadata generation to support automated speed enforcement. It shall function effectively under day/night and all-weather conditions, be capable of reading Bangladeshi number plates at high vehicle speeds, and deliver evidentiary-grade images for backend validation and ticket processing. The camera shall be seamlessly integrated with the local processing unit (LPU), radar trigger, and Traffic Management Centre (TMC).

Technical Specifications:

Description	Value / Requirement
Camera Type	4MP Motorized Radar Bullet Camera (Integrated with ANPR engine)

Image Sensor	1/1.8" CMOS, progressive scan
Resolution	≥ 1920 × 1080 pixels @ 30 fps
IR Range	≥ 50 m (with integrated IR LEDs)
Lens Type	Motorized varifocal lens
Focal Length	8–50 mm
Optical Zoom	4×
Shutter Speed	1 s to 1/100,000 s
Min. Illumination	Color: ≤ 0.002 lux @ F1.6, B/W: 0 lux with IR
WDR	≥ 140 dB
Digital Noise Reduction	2D / 3D DNR
Image Enhancements	Smart Defog, Auto/Manual Gain, Auto/Manual Focus, Auto Iris
Frame Capture Buffer	≥ 3 frames (pre/post buffer)
Recognition Rate	≥ 95% for Bangladeshi license plates
Maximum Vehicle Speed	≥ 200 km/h detection with consistent recognition
Detection Zones	Support up to 4 regions simultaneously
Trigger Mode	Integrated Doppler Radar or Image Analytics
Metadata Extraction	Vehicle number plate, direction, brand, body color, plate color, speed
White/Black List Support	Up to 1000 records in internal memory
Time Sync	GPS or NTP-based timestamping
Video Compression	H.265+, H.265, H.264+, H.264, MJPEG
Stream Options	Triple stream; main/sub/third configurable
Audio Features	Two-way audio supported; G.711, AAC, G.722, G.726 codecs
Edge Storage	Built-in MicroSD card slot, up to 256 GB
Network Interface	1× RJ45 10/100 Mbps Ethernet, IPv4/IPv6
Alarm Interface	1× Alarm Input, 1× Output; supports motion/tamper detection
Protocols	TCP/IP, HTTP(S), FTP, DHCP, DNS, SNMP, SIP, RTSP, ONVIF (S/G/T), MQTT, HTTPS, VLAN
Video Overlay	Speed, timestamp, plate number, violation marker
Power Supply	12V DC or PoE+ (IEEE 802.3at)
Max. Power Consumption	≤ 14 W
Operating Temperature	–40°C to +60°C
Humidity Range	5–95% RH (non-condensing)
Enclosure	IP67-rated, stainless steel; IK10 vandal-proof; surge-protected (TVS 4000V)
Reset & Maintenance	Hardware reset button; remote firmware update; diagnostic interface
Compliance	CE, FCC, RoHS, EN55032/35, NEMA TS2, EN 50121

7.34.3.2. Speed Detection Unit

The Speed Detection Unit shall accurately measure vehicle speeds using Doppler radar or AI-based video analytics. It shall trigger ANPR cameras upon detecting speed violations and provide precise data under multi-lane, high-speed traffic conditions. The system must support real-time processing, wide-angle detection, and high-speed tracking in all weather and lighting conditions.

Technical Specifications:

Description	Value / Requirement
Detection Technology	Doppler Radar or AI-based video analytics
Speed Measurement Range	0 – 200 km/h
Accuracy	±1 km/h
Lanes Monitored	Minimum two (02) lanes simultaneously
Detection Angle	Adjustable 0° – 45°
Trigger Output	Configurable digital trigger for camera sync
Data Output Format	XML, JSON, TCP/IP (integrated with enforcement system)
Vehicle Direction	Bidirectional detection (approaching/receding)
Environmental Sensing	Temperature, rain, and ambient light adaptive
Time Synchronization	GPS/NTP timestamping
Enclosure	IP66 / IK10 anti-vibration housing
Operating Temperature	–20°C to +60°C
Mounting	Pole or gantry, vibration-isolated
Power Supply	12–24V DC; PoE optional
Compliance	CE, EN 301489, FCC, EN 60950, RoHS

7.34.3.3. PTZ Surveillance Camera

The PTZ Surveillance Camera shall provide wide-area situational monitoring with high zoom capabilities and integrated infrared illumination. It shall support patrol mode, auto-tracking, and real-time video streaming to the TMC. The unit shall be resilient to highway vibration and environmental conditions.

Technical Specifications:

Description	Value / Requirement
Camera Type	Outdoor IP PTZ Dome Camera with AI-assisted tracking and smart alerts
Image Sensor	1/1.8" Progressive Scan CMOS, ≥ 4 Megapixels
Minimum Illumination	Color: 0.005 Lux, B/W: 0 Lux with IR
Optical Zoom	45× optical zoom
Digital Zoom	16× digital zoom
Pan Range	360° continuous rotation
Tilt Range	–20° to +90° (auto-flip supported)
Pan/Tilt Speed	Pan: 0.1°–200°/s; Tilt: 0.1°–150°/s
Preset Positions	≥ 300 presets
Preset Accuracy	±0.1°
Video Compression	H.265, H.264, MJPEG
Max. Resolution	2560 × 1440 @ 30 fps
Frame Rate	Configurable up to 60 fps
WDR	True WDR ≥ 120 dB
IR Range	≥ 250 m (Smart IR LEDs)
Day/Night Mode	Auto switch with IR-cut filter
Auto Tracking	AI-enhanced tracking for humans and vehicles

Alarm Interface	≥ 2 inputs / 1 output
Audio Support	Two-way audio, microphone, and speaker compatible
Edge Analytics	Motion detection, intrusion, line crossing, tamper detection
Network Interface	1 × RJ45 10/100 Mbps Ethernet
Protocols Supported	TCP/IP, UDP, HTTP(S), FTP, DHCP, DNS, RTSP, SNMP, ONVIF (Profile S, G, T)
Power Supply	24V AC ±10% / Hi-PoE (IEEE 802.3bt)
Power Consumption	Max. 40W with heater and IR on
Operating Temperature	−40°C to +65°C
Humidity Tolerance	0% – 95% RH (non-condensing)
Enclosure Protection	IP67 (weatherproof), IK10 (vandal-proof)
Mounting	Pole or gantry-mounted with anti-vibration support
Certifications	CE, FCC, RoHS, EN 55032/35, IEC 60529, NEMA TS-2 compliant

7.34.3.4. Speed Display Unit (SDU)

The Speed Display Unit shall function as an on-site dynamic visual alert system for drivers, indicating real-time vehicle speeds captured by the enforcement radar or video analytics unit. It shall serve both as a **compliance reinforcement tool** and a **behavioral deterrent**, using **color-coded digital feedback**. The unit must be legible in bright sunlight, compatible with roadside mounting, and durable under extreme environmental conditions.

Technical Specifications:

Description	Value / Requirement
Display Type	High-intensity LED matrix digital display
Digit Height	Minimum 300 mm (visible from ≥100 meters)
Display Resolution	Minimum 16×32 dot matrix per digit
Color Scheme	Green (within speed limit), Red (overspeed)
Character Set	7-segment numeric, supporting dynamic update
Detection Integration	Real-time interface with radar/AI speed detection units (trigger via TCP/IP or dry contact)
Response Time	< 500 milliseconds for speed refresh
Display Range	≥ 100 m under daylight, dusk, and night conditions
Brightness Control	Automatic via ambient light sensor
Display Cycle Modes	Flashing, static, slow-blink for alert escalation
Casing Material	Powder-coated aluminum or weatherproof polycarbonate
Viewing Angle	≥ 120° horizontal, 60° vertical
Ingress Protection	IP65 or higher
Mounting	Gantry or roadside pole mount with tilt-adjustable bracket
Operating Temperature	−20°C to +60°C
Power Supply	230V AC ±10%, 50Hz; Optional solar-powered battery pack
Power Consumption	≤ 100W
Interface Protocols	TCP/IP, Modbus RTU (if required for smart integration)

Safety Labeling	“YOUR SPEED” or localized equivalent message printed above LED digits
Compliance	CE, RoHS, IEC 60529, EN 55032 Class A

7.34.3.5. Local Video Image Processing Unit (VIPU)

Refer to section 7.33.3.1

7.34.3.6. High-Performance Industrial Network Switch

Refer to section 7.33.3.3

7.34.3.7. Electronic Cabinets

Refer to section 7.33.3.4

7.34.3.8. Uninterrupted Power Supply (UPS)

Refer to section 7.33.3.5

7.34.3.9. Solar lights

Refer to section 7.33.3.6

7.34.3.10. Hooter Alarms and Signal System

Refer to section 7.33.3.7

7.34.3.11. Power Connection Arrangement

Refer to section 7.33.3.8

7.34.3.12. OFC/ISP Connection Arrangement

Refer to section 7.33.3.9

7.34.3.13. Anti-theft Protection

Refer to section 7.33.3.10

7.34.3.14. Redundant Power Switching Module

Refer to section 7.33.3.11

7.34.3.15. Motion Detection Camera for Intrusion Alarm

Refer to section 7.33.3.12

7.34.3.16. Lightning Arrestor

Refer to section 7.33.3.13

7.34.3.17. Surge Protection and Grounding System

Refer to section 7.33.3.14

7.34.4. Software Requirements

The software system supporting the Automated Speed Enforcement System with Surveillance Support (ASES-SS) shall enable real-time speed detection, automatic number plate recognition (ANPR), vehicle classification, fugitive vehicle matching, and integrated traffic data analytics. The system shall be designed for edge-based processing, central enforcement management, and full interoperability with the Traffic Management Centre (TMC) and national vehicle databases (e.g., BRTA).

The ASES-SS software shall operate over a modular, IP-based architecture and use AI-driven video analytics, radar data integration, and secure data transmission protocols to support enforcement, monitoring, and reporting across highway corridors.

7.34.4.1. Core Functional Modules

Module	Functional Description
Speed Violation Engine	Processes speed readings from radar/video and correlates with ANPR output to detect violations
ANPR & Metadata Processor	Extracts plate data, vehicle features, and cross-checks with registration and watchlists
Violation Packaging System	Compiles image/video evidence, timestamp, speed data, and metadata into digitally signed packages
Surveillance Module	Provides real-time PTZ camera monitoring and remote verification capability
Traffic Flow Estimation Engine	Estimates volume, occupancy, average speed, and density per lane
System Dashboard & UI	Web-based interface for live feeds, violation records, alerts, and historical analysis
Security & Integration Framework	Manages encryption, user authentication, secure communication, and API exposure

7.34.4.2. Technical Requirements

Category	Specification
Speed Detection	Radar, LIDAR, or AI-based tracking; supports ≥ 2 lanes; 0–200 km/h; ± 1 km/h accuracy
ANPR Accuracy	$\geq 95\%$ for Bangladeshi plates at up to 200 km/h; OCR for Bangla and English
Vehicle Metadata	Type, body color, plate presence, travel direction, brand/model
Evidence Components	Full vehicle image, cropped plate view, 3–5s video, overlaid speed data
Event Response Time	≤ 1 second from detection to alert
Fugitive Detection	Real-time plate matching with law enforcement watchlists ($\geq 100,000$ records)
Dashboard Access	Browser-based, multilingual, real-time map overlay, violation filters
Data Synchronization	Auto re-sync via secure protocol with fallback caching
Reporting Formats	CSV, PDF, JPEG/MP4 export; searchable archives by time, location, plate
APIs and Protocols	RESTful API, JSON/XML; HTTPS, SNMP, MQTT, ONVIF
Security Standards	TLS 1.3+, RBAC, signed evidence packages, audit trails
Integration Interfaces	BRTA, TMC, ATMS, VMS, EMS, RCCC
Storage	Continuous + event buffer (≥ 12 hours local), real-time central sync

7.34.4.3. Functional Modules with Specifications

A. Speed Analytics & Classification Engine

This module shall perform high-accuracy speed detection and vehicle classification using edge analytics combining Doppler radar, video tracking, and ANPR fusion.

Feature	Specification
Speed Detection Method	Doppler radar, LIDAR, or AI-based tracking
Vehicle Classification	Based on shape, size, color, license plate, make/model using AI image analytics
Metadata Extracted	Speed, direction, lane number, class, license plate, time, location
Multi-lane Capability	Supports detection across a minimum of two (02) lanes
Enforcement Triggering	Configurable by speed threshold (km/h or %)
Event Time Sync	GPS or NTP-synchronized timestamps

B. Violation Packaging & Evidence Management

This module shall compile digitally signed violation packages with all visual and metadata components for enforcement and legal use.

Feature	Specification
Evidence Contents	Full vehicle image, cropped plate, short video (3–5s), overlaid speed data
Metadata Fields	Speed, limit, location, lane, timestamp, direction, plate string (Bangla/English)
Digital Signing	Secure hash and signature to ensure evidentiary integrity
Unique ID	Each violation package shall be assigned a unique, traceable event ID
Packaging Time	≤ 3 seconds from detection

C. Violation Validation & Dispute Management

This module shall allow automated and manual validation of violations, with rules for false-positive suppression and multi-parameter confirmation.

Feature	Specification
Auto Validation	Based on confidence threshold (e.g., $\geq 90\%$)
Manual Verification	TMC interface for dispute resolution or questionable cases
Persistence Rule	Speed event must persist across ≥ 2 frames or sensors
Alert Classification	Confirmed, unconfirmed, or flagged for manual review
Discard Logic	Events without a license plate or poor image quality may be auto-filtered

D. PTZ Surveillance Control & Vicinity Monitoring

The PTZ camera module shall enable manual or automated wide-area scanning, tracking, and on-demand review of violations and suspicious activities.

Feature	Specification
Manual Control	Live PTZ access from the TMC dashboard
Auto-Tracking	AI-enabled vehicle or object tracking during events
Tamper/Intrusion Alerts	Trigger PTZ snapshot if intrusion or tampering is detected
Integration	Linked with violation records and LPU for contextual footage

E. Traffic Flow Estimation Engine

This module shall provide real-time flow parameters to support traffic monitoring, congestion analysis, and performance benchmarking.

Feature	Specification
Metrics Tracked	Vehicle count, average speed, occupancy, density per lane
Direction-wise Analysis	Inbound/outbound flows, cross-direction volume
Detection Method	ANPR-based tracking and virtual loop estimation
Output Interval	Configurable (e.g., per minute, 5-minute, hourly)
Data Format	CSV, JSON, or SQL-interfaced

F. User Interface & Dashboard

A browser-based interface shall be provided for real-time visualization, alert review, system diagnostics, and violation record management.

Feature	Specification
UI Type	Web-based, responsive, multilingual

Real-Time Visualization	Speed display, violation overlays, map-based location plots
Filtering Options	By date, time, plate, location, event type
Export Capabilities	PDF, CSV, JPEG snapshots, video footage
User Roles	Multi-user, RBAC (read-only, enforcement officer, admin, etc.)

G. Communication & API Integration

This module shall ensure the system is interoperable with external databases, enforcement platforms, and ITS modules.

Feature	Specification
API Support	RESTful APIs with JSON/XML payloads
Supported Protocols	HTTPS, MQTT, SNMP, ONVIF, RTSP
Integration Targets	BRTA registration DB, TMC, ATMS, VMS, RCCC
Sync Handling	Automatic retry/reconnect if transmission fails

H. Reporting & Data Export Module

An internal reporting module shall generate structured enforcement reports and system performance logs for decision-making and compliance.

Feature	Specification
Report Types	Violation summary, offender heatmaps, peak hour violations, equipment uptime
Export Formats	CSV, Excel, PDF, JSON
Filter Templates	Time range, lane, vehicle class, speed range
Automated Distribution	Scheduled email delivery of reports
System Log Archiving	Device status, downtime records, sync failures

I. Intellectual Property Rights (IPR)

IPR Element	Specification
Ownership	RHD shall retain full intellectual property rights over source code and AI models
Source Code Delivery	Complete codebase (backend + frontend) delivered to RHD
Customizability	Fully modifiable and re-deployable without vendor lock-in
Third-party Components	Only royalty-free or open-source components permitted
Reuse Restrictions	Vendor shall not reuse, license, or replicate the system without RHD approval

7.34.4.4 Performance Requirements

Functionality	Target Performance
Speed Violation Detection	≥ 98% accuracy; < 1s latency
Plate Recognition Accuracy	≥ 95% (day/night, all-weather)
Violation Packaging & Transmission	Within 3 seconds of detection
Fugitive Alert Response	Instantaneous alert on match
PTZ Surveillance Verification	Real-time manual review interface
Traffic Flow Estimation Accuracy	Volume: ≥ 97%, Speed: ±3 km/h

Data Integrity	Tamper-evident, audit-logged packages
Uptime Requirement	≥ 99% system availability

7.34.5. Installation of Supporting Structures and Appurtenances

See section 7.33.5

7.34.6. Testing and Commissioning

The testing and commissioning of the **Automated Speed Enforcement System with Surveillance Support (ASES-SS)** shall be carried out in well-defined phases to validate the functionality, accuracy, integration, and operational resilience of all hardware and software subsystems before final handover. All tests shall be conducted under the supervision of the Engineer and in the presence of authorized representatives from the Roads and Highways Department (RHD).

7.34.6.1. Factory Acceptance Test (FAT)

The Contractor shall conduct FAT for all major system components, including the ANPR & violation detection cameras, radar units, local processing units (LPUs), PTZ surveillance cameras, Speed Display Units (SDUs), and associated software. FAT shall be carried out before shipment to the installation sites and shall include:

- Verification of hardware compliance with approved technical specifications.
- Demonstration of ANPR accuracy, radar speed detection, and evidence packaging functionalities using test scenarios.
- Software dashboard interface validation, including live video, violation logs, and event analytics.
- Communication protocol compliance (TCP/IP, ONVIF, HTTPS, SNMP).
- 48-hour continuous endurance test under simulated conditions.
- Failure simulation tests (e.g., power loss, network disruption) and system response.

7.34.6.2. Site Acceptance Test (SAT)

Upon installation at designated field locations, the SAT shall be conducted to validate the site readiness, installation quality, and functional performance of each deployed ASES-SS unit. The SAT shall include:

- Physical verification of installation (camera alignment, mounting height, angle of detection, PTZ coverage).
- Testing of power supply switching (grid, UPS, solar if applicable) and alarm triggering on power failure.

- Verification of real-time connectivity between field devices and the Traffic Management Centre (TMC).
- Live test of speed violation detection accuracy and ANPR performance across all installed lanes.
- Validation of SDU functionality (correct color-coded speed display).
- Verification of hooter/alarm activation for defined enforcement scenarios (wrong-way entry, system tampering).
- Testing of PTZ camera control, streaming, and manual override functionality.
- Data buffering, local storage, and central synchronization under network fluctuation.
- Redundancy test of power and communication pathways.

7.34.6.3. Integrated System Test

An Integrated System Test (IST) shall be performed under live highway traffic conditions to validate end-to-end performance of the entire ASES-SS system. The IST shall confirm:

- Real-time detection, processing, and TMC transmission of overspeeding violations.
- Violation of packaging integrity and back-end event management from LPU to the central database.
- PTZ surveillance integration for live and recorded footage review.
- Communication and data flow with integrated ITS modules (e.g., VMS, ATMS, ANPR database).
- Violation ticket workflow simulation, including evidence export and report generation.
- System response benchmarks for detection-to-alert latency, verification interface responsiveness, and SDU actuation.

7.34.6.4. Provisional Acceptance Test (PAT)

Following successful SAT and IST, a **30-day Provisional Acceptance Test** period shall commence, during which the installed system shall be continuously monitored to assess stability and sustained performance. PAT criteria include:

- 24/7 system uptime with no critical failures or repeated errors.
- Sustained ANPR and speed detection accuracy at $\geq 95\%$.
- Alert generation, evidence packaging, and SDU updates functioning as per specifications.
- Successful remote device health checks and diagnostics from TMC.
- Auto-recovery from simulated failures (e.g., power restart, network failover).
- Consistent archiving and central access of violation records.

7.34.6.5. Final Acceptance and Handover

Final Acceptance shall be granted upon completion of the PAT phase, submission of required deliverables, and full compliance with contractual obligations. The following shall be required:

- Formal validation of PAT results by the Engineer and RHD representatives.
- Submission of:
 - As-built installation drawings and configuration layouts.
 - Operation and maintenance manuals.
 - Software source code, configuration files, and perpetual licenses (per IPR clause).
- On-site training for RHD personnel covering operation, monitoring, and first-line maintenance.
- Delivery of all spares, tools, and accessories as specified in the BOQ.
- Final system performance report, including detection accuracy logs, device uptime records, and incident handling summaries.

7.34.8. Measurement

The measurement for the Automated Speed Enforcement System with Surveillance Support (ASES-SS) shall cover the complete scope of work required to deliver a fully functional, centrally integrated, and enforcement-ready solution. The system shall include the design, supply, installation, integration, testing, commissioning, and training of all hardware, software, and communication components, as well as their configuration with the central Traffic Management Centre (TMC). The Contractor shall be responsible for delivering the system in full compliance with the Roads and Highways Department (RHD) standards and shall ensure that all items are fully installed, operational, and interoperable before being considered for measurement.

Each ASES-SS site shall be measured based on the number of completed enforcement nodes and fully functional system components. Measurement shall include all installed speed detection units, ANPR and violation detection cameras, Speed Display Units (SDUs), PTZ surveillance cameras, and Local Processing Units (LPUs), along with their associated support systems, including equipment cabinets, UPS units, network switches, hooter alarms, communication devices, and field wiring. All field devices shall be considered measurable only after verification of correct installation, system integration, and operational readiness as per approved test protocols.

System software shall be measured on a per-system basis, inclusive of all modules deployed at the TMC and local enforcement nodes. This includes the enforcement dashboard, violation data interface, alert management features, and integration with external systems. Software shall only be measured after successful end-to-end testing, license handover, and submission of administrative tools and user documentation to RHD.

All optical fiber or cellular communication links between the enforcement sites and the TMC shall be measured upon completion of installation, termination, testing, and demonstration of live data transmission. Associated accessories such as patch panels, communication cabinets, or modems shall be considered part of the communication system and measured accordingly.

Testing, commissioning, and training shall be measured as a lump sum per ASES-SS deployment package. This shall include Factory Acceptance Testing (FAT), Site Acceptance Testing (SAT), Integrated System Testing (IST), Provisional Acceptance Testing (PAT), and end-user training for designated RHD personnel. Training deliverables, such as manuals, SOPs, and support documentation, must be submitted before final approval.

All hardware, software, and communication components shall be considered part of an integrated enforcement system. No individual component shall be accepted for measurement until it is fully installed, integrated, and confirmed to be functioning as part of the complete ASES-SS solution. Partial or non-operational installations, or those not interfaced with the TMC, shall not be accepted for payment.

Related civil works, including trenching, ducting, pole foundations, and earthing, shall be measured separately under their respective BOQ items. However, ASES-SS systems dependent on these civil works shall not be considered complete until all related items are installed and functional.

Final measurement and payment shall be subject to the successful completion of the system, submission of all as-built documentation, commissioning logs, configuration backups, test reports, software licenses, and formal certification of acceptance by the Engineer.

7.34.9. Payment

Payment for the Automated Speed Enforcement System with Surveillance Support (ASES-SS) shall be made on the basis of the complete delivery of a fully integrated, operational, and centrally monitored speed enforcement and surveillance solution along designated highway corridors or enforcement zones, as approved by the Engineer. The payment items listed below cover all critical system components, including detection equipment, ANPR systems, enforcement software, communication infrastructure, and associated installation, testing, and commissioning works.

These items may be extended, adjusted, or optimized based on evolving ITS requirements, enforcement standards, or specific site conditions. Civil and structural works such as foundations, trenching, pole erection, earthing, ducting, and access pathways shall be paid under separate BOQ items in accordance with the relevant sections of the RHD Technical Specification.

Pay items shall be subject to further breakdown and disaggregation as per actual implementation requirements and at the discretion of the Engineer. This may include adjustments in units, system configurations, deployment phasing, or integration modalities depending on site-specific conditions, system evolution, or stakeholder coordination protocols.

Pay Item No.	Description	Unit
7.34.1	Supply, installation, testing, and commissioning of Radar-based or AI-based Speed Detection Unit with lane-specific calibration and directional configuration	Number
7.34.2	Supply and installation of ANPR and Violation Detection Camera (≥ 2 MP, IR-enabled, IP67-rated, OCR engine for Bangla/English, integrated triggering)	Number
7.34.3	Supply and installation of Speed Display Unit (SDU) with ≥ 300 mm LED digits, ambient light sensor, red/green display mode, and roadside pole/gantry mounting	Number
7.34.4	Supply and installation of PTZ Surveillance Camera ($\geq 35\times$ optical zoom, auto-tracking, IP66-rated, TMC-controllable) with pole/gantry mounting	Number
7.34.5	Provision of Edge-based Local Processing Unit (LPU) with AI inference engine, event packaging, violation database, and data buffering capability	Number
7.34.6	Supply and deployment of ASES-SS Enforcement Software Platform, including violation detection, metadata extraction, report generation, and dashboard access	Per Site
7.34.7	Provision and configuration of ASES-SS Violation Packaging and Evidence Engine (speed info, plate data, images, video clip, and digital signature)	Per Site
7.34.8	Supply and installation of an IP66-rated Outdoor Field Cabinet for housing LPU, UPS, and switching components, with cooling and alarm module	Number
7.34.9	Supply and installation of 8/16-port Industrial PoE Switch with dual uplinks, IP30 enclosure, and redundant power supply	Number
7.34.10	Supply and commissioning of Online UPS (≥ 1.5 kVA, ≥ 4 -hour backup) with Li-ion/VRLA batteries for powering ANPR, radar, and processing units	Number
7.34.11	Provision and installation of OFC or Cellular Communication Unit with modem/router, antenna, IP-rated enclosure, and secure transmission setup	Number
7.34.12	Supply and installation of Anti-Theft Intrusion Detection System for field equipment, including motion sensor, night IR camera, and alarm integration	Number
7.34.13	Supply and configuration of Redundant Power Switching Unit (ATS) for switching between grid, UPS, and optional solar backup	Number
7.34.14	Provision of Lightning Arrestor (≥ 40 kA capacity) and grounding network for field electronics, compliant with IEC standards	Number
7.34.15	Supply and installation of Surge Protection and Grounding System for poles, cabinets, and electronics with earth pit, rods, and SPD panels	Per Site

7.34.16	Supply and deployment of the Traffic Flow Analysis Module for lane-wise vehicle count, speed profiling, and occupancy analytics	Per Site
7.34.17	Integration of ASES-SS Software Platform with TMC dashboards, RCCC nodes, and BRTA vehicle registration database	Lump Sum
7.34.18	Final Testing, Commissioning, and Acceptance Trials of the complete ASES-SS system, including all nodes, field validations, and report generation	Lump Sum
7.34.19	Operation and Maintenance of the deployed ASES-SS solution, including preventive maintenance, software patching, and remote diagnostics for x years	Per Year
7.34.20	Training of RHD engineers, enforcement operators, and administrative staff on software usage, alert handling, evidence review, and system configuration	Lump Sum
7.34.21	Training of field staff and maintenance teams on device care, physical inspections, fault handling, and replacement procedures	

7.35. Road Weather/Environment Information System (RWIS)

7.35.1. General

The Road Weather Information System (RWIS) shall serve as an integrated field-to-center platform for monitoring, analyzing, and disseminating weather and pavement condition data relevant to roadway safety and operations. The system shall consist of Environmental Sensor Stations (ESS), centralized data acquisition and control units, reliable communication networks, and user-interface software at the Traffic Management Centre (TMC). The RWIS shall support real-time decision-making during adverse weather events such as fog, storms, floods, or low-surface temperatures, ensuring safer road conditions and timely intervention. RWIS can be installed as a stand-alone system or as integrated with the existing ITS systems like VIDS or ASES-SS.

7.35.2. Siting Standards

The reliability and effectiveness of the Road Weather Information System (RWIS) depend significantly on the correct siting of its Environmental Sensor Stations (ESS). Proper siting ensures the collection of accurate, representative, and operationally useful road and weather condition data. This section establishes the siting standards for RWIS installation under the Roads and Highways Department (RHD), based on internationally recognized guidelines and research from the Federal Highway Administration (FHWA, 2004), the Strategic Highway Research Program (SHRP, 2003), and the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM, 1994).

A. General Siting Objectives

RWIS ESS shall be located in positions that:

- Provide climatologically representative data for roadway safety operations.
- Minimize non-natural influences (e.g., artificial heat, shadowing, exhaust).
- Align with RHD's operational priorities, including visibility monitoring, flood detection, and fog/heavy rain/storm alerts.
- Enable robust communication with the Traffic Management Centre (TMC) and other ITS subsystems.

Sensor siting must be application-specific and adhere to FHWA's *Road Weather Management RWIS Siting Guidelines* (FHWA-HOP-05-026, 2005).

B. Sensor-Specific Siting Criteria

1. Pavement Condition Sensors

- Shall be embedded or surface-mounted on representative pavement segments within **mainline travel lanes**, not on shoulders or turn bays.
- Must be placed away from manholes, patch repairs, bridge decks, and other **non-standard road sections**.
- Locations near intersections, ramps, culverts, or bridges should be avoided unless freeze-prone areas are being specifically targeted.

(Ref: SHRP RWIS Implementation Guide, 2003)

2. Meteorological Sensors

Sensor Type	Siting Requirement
Air Temperature & RH	Mounted at 1.5–2.0 m above ground; at least 10 m away from buildings, HVAC, pavement, or vegetation that may introduce microclimate bias
Wind Speed/Direction	Installed at a standard height of 10 m , in an open area with no vertical obstructions within 10× obstacle height
Visibility	Positioned at fog-prone or haze-prone segments , with a clear line of sight and away from direct sunlight during low-angle hours
Rain/Flood Sensors	Located in low-lying or flood-susceptible areas , away from overhead structures that may block rainfall

(Ref: FHWA RWIS Siting Guidelines, 2005; OFCM FCM-S4-1994)

C. Urban vs. Rural Deployment Criteria

Parameter	Urban Areas	Rural Areas

Structural Proximity	≥10 m from buildings, generators, or chimneys	≥30 m from any major obstructions or tree lines
Sun Exposure	Full solar access between 9:00 AM and 3:00 PM	No artificial shade or reflection from structures
Maintenance Access	Accessible without disrupting primary lanes	All-weather access route to be ensured
Power Source	Utility grid, UPS, or solar hybrid system	Solar + battery recommended for standalone deployment

(Ref: SHRP RWIS Guidelines, 2003)

D. Network-Wide Sensor Spacing

- RWIS stations shall be spaced according to **climatic and topographic variability**, not fixed distance.
- In mountainous or coastal regions, stations may be placed **10–20 km apart**.
- On homogeneous flat terrain, spacing may extend up to **30–50 km** between stations.
- Priority siting shall target:
 - **Crash-prone segments with a weather correlation**
 - National highways and high-speed corridors
 - Locations requiring coordination with VMS, ASES-SS, or TMS systems

(Ref: FHWA-HOP-05-026)

E. Structural and Environmental Requirements

- All ESS structures shall be designed to withstand **wind speeds up to 200 km/h**.
- Electrical systems must be protected by **lightning arrestors** and **Type II surge protection devices (SPD)**, with grounding resistance ≤ 10 ohms.
- ESS enclosures shall be:
 - **IP66-rated**, corrosion-resistant, and tamper-proof
 - Mounted on **galvanized poles or gantries** with minimal vibration
 - Located in **non-floodable zones** or on **raised platforms** in flood-prone areas
- All cabling must be protected in **UV-stabilized conduits** or underground armored ducts.

F. Documentation and Approval

- A **Siting Validation Report** must be submitted for each RWIS location, including:
 - GPS coordinates
 - 360° site photographs

- Obstacle clearance sketch (minimum 100 m radius)
 - Justification based on siting criteria and data requirements
- The Engineer reserves the right to request site relocation if the proposed location does not meet standard siting or operational suitability requirements.

7.35.3. Calibration Standards

Calibration of Road Weather Information System (RWIS) sensors is essential to ensure the accuracy and reliability of real-time environmental and road condition data. All sensors shall be subject to laboratory and field calibration before commissioning, and recalibrated periodically in compliance with internationally recognized standards.

A. Calibration Requirements

1. **Laboratory Calibration**
 - Conducted prior to deployment by ISO/IEC 17025-accredited laboratories.
 - Calibration certificates must detail test methods, tolerances, and uncertainty.
2. **Field Calibration**
 - Performed upon installation to validate site-specific performance.
 - Procedures must follow manufacturer instructions and CEN/TS 15518-4 methods.
3. **Routine Recalibration**
 - Recommended annually, or per manufacturer guidance.
 - Recalibration records must be maintained for all sensors.

B. Documentation and Quality Assurance

- Calibration logs, certificates, and maintenance records shall be archived by the Contractor and submitted to RHD.
- Any deviation or failure in calibration shall trigger corrective action and retesting.

7.35.4. Communication Standards

Reliable and secure communication is critical for the effective operation of RWIS. The communication subsystem shall ensure uninterrupted data flow between field-deployed Environmental Sensor Stations (ESS) and the central Traffic Management Centre (TMC) or designated data servers. The system shall support both real-time transmission and buffered synchronization during outages.

A. General Requirements

- All RWIS communication shall be based on **IP-based networking** with support for **redundant paths** (e.g., fiber and cellular).

- Data protocols must support **low-latency, secure, and fault-tolerant** transfer of weather and sensor data.
- Communication systems must comply with **NTCIP¹⁹ 1204 v03, ISO 21210²⁰**, or other internationally recognized ITS data exchange standards.

B. Communication Architecture

- **Primary Communication:** Fiber-optic cable (OFC) or 4G/5G LTE with secured VPN tunnel to the TMC.
- **Backup Communication:** Automatic switchover to cellular or satellite-based link in case of OFC failure.
- **Local Data Buffering:** Minimum 7-day onboard data retention in each Data Acquisition Controller in case of transmission loss.

C. Protocol and Interface Support

- All RWIS components shall support:
 - **NTCIP 1201/1203** (Center-to-Field)
 - **HTTPS, SNMP, FTP/SFTP**, and **MQTT** for data push/pull.
 - **RS-485, RS-422**, and **Ethernet (RJ45)** interfaces.
 - Compatibility with **IPv4 and IPv6** addressing.

D. Data Security and Reliability

- All communication must be encrypted using **TLS 1.2 or higher**.
- Devices shall support **two-factor authentication** for remote access.
- Firewalls and intrusion detection systems shall be integrated at all communication endpoints.
- Data integrity checks (checksum, CRC) shall be applied during transmission.

E. Network Management and Diagnostics

- RWIS shall include Simple Network Management Protocol -based remote monitoring for all connected sensors and devices.
- System shall provide real-time **health status** updates, bandwidth usage, link failures, and retry logs.
- Event-driven notifications shall be transmitted to the TMC in the event of communication disruption or packet loss.

F. Power and Protection

¹⁹ National Transportation Communications for Intelligent Transportation System Protocol

²⁰ IPv6 Networking in ITS

- All communication equipment shall be protected with **surge suppressors** and **power isolators**.
- Communication enclosures must be **IP65-rated** and thermally protected for high-humidity and high-temperature environments.

7.35.5. System Components

The Road Weather Information System (RWIS) shall comprise modular, interoperable subsystems designed for 24/7 environmental monitoring and integration with the Traffic Management Centre (TMC). The following are the core components:

1. Environmental Sensor Station (ESS)

The ESS shall serve as the primary data collection node and shall include:

- **Meteorological Sensors:**
 - Air temperature
 - Relative humidity
 - Wind speed and direction
 - Precipitation (rain/snow intensity and type)
 - Visibility (fog, haze)
- **Pavement Condition Sensors:**
 - Surface temperature
 - Surface state detection (wet, dry)
 - Flooding detection: Detection of standing water or flooded conditions through dedicated ultrasonic or capacitive water level sensors or via advanced road surface sensors capable of measuring water accumulation beyond standard film height (e.g., >5 mm). Alarms should be triggered when thresholds are exceeded.
- **Roadside Camera (optional):**
 - For visual verification of road and weather conditions (image capture every 5–15 minutes)

2. Remote Processing and Data Acquisition Unit (RPU)

- NTCIP-compliant and programmable
- Equipped with local data storage for a minimum of 7 days
- LCD interface for on-site sensor diagnostics and configuration
- Integrated power management and watchdog timer
- Onboard support for timestamping, data validation, and input/output logic

3. Communication Infrastructure

- Communication via any of the following (redundant preferred):
 - 4G/5G Cellular (VPN-based)
 - Fiber-optic network
 - Satellite (for remote sites)
- Support for standard protocols:
 - **NTCIP 1201/1203, Modbus, FTP/SFTP, TCP/IP, MQTT, HTTP/HTTPS**
- Encrypted data transmission using **TLS 1.2 or higher**
- Remote firmware update and system diagnostics

4. Central Software and Dashboard

- Web-based monitoring platform with multi-level access control
- Real-time display of sensor readings and weather status
- Configurable alerts and thresholds for event detection
- Historical data visualization with CSV/PDF export
- API-based data sharing with external systems (e.g., ATMS, TMS, VMS)

7.35.6. System Requirements

A. Meteorological Sensors

Sensor Type	Specification
Air Temperature	Range: -30°C to $+70^{\circ}\text{C}$; Accuracy: $\pm 0.3^{\circ}\text{C}$; Resolution: 0.1°C
Relative Humidity	Range: 0–100% RH; Accuracy: $\pm 2\%$; Resolution: 0.1% ; Dust and pollution protected
Wind Speed	Range: 0–79 m/s; Accuracy: $\pm 2\%$; Threshold: < 0.3 m/s
Wind Direction	Accuracy: $\pm 5^{\circ}$; Damping Ratio: ≥ 0.7
Visibility	Range: 50–1500 m; Infrared (880 nm); Accuracy: $\pm 15\%$; Self-cleaning preferred
Precipitation	Type: Rain/Snow; Measures intensity and type; Accuracy per WMO standards

B. Pavement Condition Sensors

Sensor Type	Specification
Surface Temperature	Range: -10°C to $+60^{\circ}\text{C}$; Accuracy: $\pm 0.2^{\circ}\text{C}$; Resolution: 0.1°C
Surface Condition	Wet/Dry/Ice/Snow detection; Measures water film depth and estimates freezing point
Flood Detection (Opt.)	Ultrasonic or capacitive; Alarm on configurable threshold exceedance
Subsurface Temperature	Up to two depths (e.g., 5 cm & 30 cm); Accuracy: $\pm 0.2^{\circ}\text{C}$

C. Data Acquisition Unit (Remote Processing Unit – RPU)

Component	Specification
Protocol Compliance	NTCIP 1204; also supports Modbus, SNMP, MQTT, FTP, HTTPS
Interfaces	RS-485, RS-232, RJ-45 Ethernet, USB (for local service/update)
Local Diagnostics	LCD or OLED screen; Status indicators; Local data logging
Data Storage	≥ 7 days non-volatile onboard memory

Power Management	Watchdog timer, battery health monitoring, smart switching
OTA Update	Supports over-the-air firmware upgrades
Mounting	Cabinet-integrated; DIN rail installation with environmental shielding

D. Physical Infrastructure and Power

Component	Specification
Power Supply	Solar + Battery Backup (≥ 3 days) or Grid + UPS + Surge Protection
ESS Enclosure	IP66-rated, tamper-proof, -40°C to $+70^{\circ}\text{C}$ operating range
Mounting Structure	Galvanized steel pole or gantry; Wind resistance ≥ 200 km/h

7.35.7. Functional Capabilities

The RWIS system shall be capable of performing the following functions reliably under all weather conditions:

- **Continuous, real-time monitoring** of meteorological and pavement surface data.
- **Detection of freezing potential**, including prediction of surface frost and black ice risk using subsurface thermal profiling (where applicable).
- **Event-based alerting** for hazardous conditions, including:
 - Fog and reduced visibility
 - Wind gusts/storm
 - Rain or snow accumulation
 - Flood
- **Visual status verification** using optional on-site cameras for contextual support to sensor data.
- **Configurable multi-level alerts** to the TMC dashboard, maintenance operators, or external systems.
- **Remote configuration and diagnostics** via secure communication interface.
- **Data logging and synchronization** with buffering during communication outages.
- **Interoperability** with other ITS modules (e.g., VMS, ATMS, ASES-SS) via open APIs and protocol support.

7.35.8. Installation of Supporting Structures and Appurtenances

See section 7.33.5

7.35.9. Measurement

The measurement for the Road Weather Information System (RWIS) shall encompass the complete scope of activities required to deliver a fully operational, integrated, and centrally managed weather and (or) pavement condition monitoring system. The system shall include the design, supply, installation, calibration, integration, configuration, testing, commissioning, and training associated

with the RWIS solution. The Contractor shall be fully responsible for delivering a complete, Traffic Management Centre (TMC)-integrated solution compliant with Roads and Highways Department (RHD) standards, communication protocols, and ITS interoperability requirements.

Each RWIS installation site shall be measured based on the number of deployed Environmental Sensor Stations (ESS) and associated functional subsystems. Measurement shall include meteorological sensors, road condition sensors, subsurface temperature probes (where applicable), Remote Processing Units (RPU), communication modules, mounting structures, enclosures, surge protection devices, and power supply systems (solar, battery, or grid-based). All associated accessories, including poles, weather shields, cables, and brackets, shall be measured as part of the respective subsystem.

The Environmental Sensor Station (ESS) shall be measured per unit, inclusive of all sensors, enclosures, IP-rated protection, and mounting hardware. Subsurface sensors, if provided, shall be measured per depth level. Data Acquisition and Control Units (RPU) shall be measured per unit, inclusive of internal storage, communication interface, and field diagnostic display.

The communication infrastructure, including cellular, satellite, or optical fiber linkages, shall be measured upon installation, configuration, and successful demonstration of real-time and buffered data transfer to the TMC. Fiber terminations, modems/routers, patch panels, and secure communication enclosures shall be included in the corresponding item measurement.

Centralized RWIS software, including real-time monitoring dashboard, historical data analytics, alert generation, API integrations, and system diagnostics, shall be measured on a per-system basis. This includes deployment at the TMC, full data pipeline integration, interface configuration, and connectivity with other ITS systems (e.g., VMS, ASES-SS, VIDS). Software measurement shall only be accepted upon successful test validation, licensing handover, and administrative credential provisioning to RHD.

All system components shall be measured only after installation, verification of functionality, and demonstration of real-time environmental data acquisition under standard and adverse weather conditions. Measurement shall be supported by on-site testing logs, communication performance records, and calibration documentation.

The RWIS system shall be treated as an integrated platform; no partial component or disconnected subsystem shall be measured or accepted for payment unless it has been fully commissioned and integrated with the TMC. Measurements for incomplete, non-communicating, or non-calibrated devices shall be disqualified.

Testing, commissioning, and training shall be measured as a lump sum per RWIS deployment package. This shall include Factory Acceptance Testing (FAT), Site Acceptance Testing (SAT), Integrated

System Testing (IST), Provisional Acceptance Testing (PAT), and end-user training for designated RHD personnel. Training deliverables, such as manuals, SOPs, and support documentation, must be submitted before final approval.

All related civil works, such as foundation preparation, trenching, earthing, ducting, and pole installation, shall be measured separately under the corresponding BOQ items. However, the RWIS installation shall not be considered complete unless all dependent civil works are functional and certified.

7.35.10. Payment

Payment for the Road Weather Information System (RWIS) shall be made on the basis of the full delivery, installation, integration, and successful commissioning of a complete, centrally monitored, and operational system along designated highway corridors or identified climate-sensitive zones, as approved by the Engineer. The payment items listed below cover all essential system components, including environmental sensors, data acquisition units, communication infrastructure, software platforms, and associated testing, calibration, and training activities. Essential devices and components for RWIS can be installed on the same mounting structures of VIDS, ASES-SS, or VMS.

These items may be extended, adjusted, or optimized based on evolving ITS requirements, enforcement standards, or specific site conditions. Civil and structural works such as foundations, trenching, pole erection, earthing, ducting, and access pathways shall be paid under separate BOQ items in accordance with the relevant sections of the RHD Technical Specification.

Pay items shall be subject to further breakdown and disaggregation as per actual implementation requirements and at the discretion of the Engineer. This may include adjustments in units, system configurations, deployment phasing, or integration modalities depending on site-specific conditions, system evolution, or stakeholder coordination protocols.

Pay items shall be:

Pay Item No.	Description	Unit
7.35.1	Supply, installation, and commissioning of Environmental Sensor Station (ESS) with air temperature, humidity, wind, precipitation, visibility, and road condition sensors	Number
7.35.2	Provision and installation of flood detection sensors (ultrasonic or capacitive type) integrated with ESS	Number
7.35.3	Supply and installation of Subsurface Temperature Probes (at two depths), IP-rated and compatible with ESS controller	Number
7.35.4	Provision of Roadside Surveillance Camera (optional), weather-resistant, image capture interval 5–15 min, IP66-rated	Number

7.35.5	Supply and installation of Remote Processing Unit (RPU) with 7-day local storage, NTCIP-compliant, with LCD diagnostics interface	Number
7.35.6	Supply and deployment of Communication Module (OFC, 4G/5G or Satellite) with secure transmission (TLS 1.2 or higher) and redundant failover configuration	Number
7.35.7	Provision and configuration of Web-based RWIS Central Software, including dashboard, live monitoring, historical analytics, and alert management system	Per Site
7.35.8	Supply and configuration of Data Synchronization and API Integration Suite for sharing with external systems (e.g., TMS, ATMS)	Per Site
7.35.9	Supply and installation of IP66-rated Outdoor ESS Enclosure with thermal protection, vandal-resistance, and pole mounting system	Number
7.35.10	Provision of Power Supply System (Solar + battery backup min. 3 days) or Grid + UPS configuration with surge protection	Number
7.35.11	Supply and installation of Grounding and Lightning Protection System for ESS and communication electronics, resistance ≤ 10 ohms	Number
7.35.12	System Calibration (Laboratory and Field) of all installed sensors as per ISO/IEC 17025 and CEN/TS 15518-4 standards, with traceable certification	Lump Sum
7.35.13	Final Testing, Commissioning, and Acceptance Trial of the complete RWIS system, including validation of siting, data flow, diagnostics, and alerts	Lump Sum
7.35.14	Training of RHD personnel on RWIS usage, diagnostics, calibration logs, alert management, and routine maintenance	Lump Sum

7.36. Emergency Management System (EMS)

7.36.1. General

Emergency Management Systems (EMS), within the framework of Intelligent Transport Systems (ITS), refer to integrated technologies and protocols that support the timely detection of traffic incidents/accidents, hazardous events, or disasters, real-time communication with emergency response agencies, coordinated intervention across multiple stakeholders, and effective response and recovery actions affecting road users, transport infrastructure, and service operations. EMS shall interoperate with other ITS components such as the Video Incident Detection System (VIDS), Automated Speed Enforcement System (ASES), Variable Message Signs (VMS), Road Weather Information System (RWIS), and the Traffic Management Center (TMC).

7.36.2. Generic Requirements

The primary objective of the Emergency Management System (EMS) is to reduce fatalities, serious injuries, and long-term traffic disruptions resulting from road crashes and other highway-related emergencies. This will be achieved by establishing a responsive, technology-enabled system that integrates medical response, incident detection, stakeholder coordination, and real-time communication across designated highway corridors and the Traffic Management Center (TMC) infrastructure.

The specific objectives of the EMS shall be as follows:

- Establish a robust post-crash response framework in alignment with national and international standards (e.g., Standard protocols of the Non-Communicable Disease Control (NCDC) Program under the Directorate General of Health Services (DGHS).
- Deploy and operate 24/7 emergency ambulance and bike ambulance services, each equipped with trained Emergency Medical Technicians (EMTs) and stocked with essential pre-hospital care equipment to deliver trauma response along selected highway corridors.
- Operate a toll-free, 24/7 emergency call center, fully integrated with the TMC and other ITS components to enable centralized incident coordination, real-time dispatch, and continuous monitoring of emergency response units.
- Mobilize and train community-based volunteers along national highways to act as first responders for bystander care.
- Expand the EMS scope beyond post-crash medical care to cover a wide range of highway emergencies, including fire incidents, flooding, extreme weather conditions, vehicle breakdowns, hazardous spills, and long traffic queues, thereby ensuring resilience of the road network.
- Facilitate coordinated response efforts by integrating operational protocols across all relevant stakeholders, including Highway Police, Fire Service, Civil Defense, Health Complexes, District and Local Administrations, and other emergency service agencies.

7.36.2. Functional Requirements

7.36.2.1. Scope

The functional scope of EMS shall include, but not be limited to:

1. Establishment of Emergency Operations Infrastructure:

- Develop and operate a centralized **Emergency Call Center** linked to the **Traffic Management Center (TMC)** with full redundancy, staffed by trained dispatchers and integrated with ITS systems for real-time incident detection and response coordination.
- Set up and maintain a **Project Office** for field coordination, logistics, record-keeping, and supervision of response operations and community engagement.

2. Deployment of Emergency Medical Response Units:

- Operate **24/7 ambulance and bike ambulance services** with GPS tracking and real-time status updates to the TMC.
- Ensure each unit is staffed by certified **Emergency Medical Technicians (EMTs)** and stocked with essential trauma and stabilization supplies for pre-hospital care.

3. **Community Volunteer Mobilization and Training:**

- Identify, recruit, and train **local volunteers** along the designated highway corridor to provide immediate bystander support for road crash victims.
- Conduct regular **orientation and sensitization sessions** with communities and commercial drivers, providing outreach materials such as banners, leaflets, and basic first-aid kits.

4. **Emergency Response Integration with ITS Systems:**

- Utilize data and alerts from **Video Incident Detection Systems (VIDS)**, **Automated Speed Enforcement Systems (ASES)**, and **Road Weather Information Systems (RWIS)** to automatically trigger EMS responses at TMCs, and generate dynamic messages through **Variable Message Signs (VMS)**.
- Ensure **real-time synchronization** between on-ground EMS personnel and the TMC for situational updates, incident logging, and post-incident analytics.

5. **Stakeholder Coordination:**

- Facilitate operational coordination with **Highway Police, Fire Service, District Hospitals, Upazila Health Complexes, and Local Disaster Management Committees** to ensure an end-to-end emergency response chain.

6. **Response to Non-Medical Highway Emergencies:**

- Develop and maintain emergency response protocols for **fire incidents, flooded road sections, long traffic queues, hazardous material spills, and storm-related disruptions**.
- Coordinate with VIDS, RWIS, and TMC systems to issue **real-time warnings** to road users via VMS and mobile alerts.

7. **Monitoring, Reporting, and Evaluation:**

- Maintain comprehensive logs of each emergency response including incident time, response time, field actions, and outcomes.
- Submit periodic performance and impact evaluation reports aligned with KPIs specified by RHD and DGHS.

7.36.2.2. **Emergency Classification**

Table 7.36-1 presents a practical classification of emergency incidents detectable through the ITS subsystems, highway police patrol services, or RHD iMAP responders, structured to guide EMS response prioritization. Given the inherent limitations of video analytics in assessing medical severity, crash-related incidents are categorized based on the potential for fatality or injury as inferred from visual characteristics, scene context, and traffic disruption. Non-crash incidents are classified according to their operational impact on roadway safety and flow, following a three-tier system: Minor,

Intermediate, and Major. The classification is designed to support initial dispatch decisions at the Traffic Management Center (TMC), with updates permitted based on real-time verification and field responder input.

Table 7.36-1: Classification of emergency incidents.

Incident Type	Classification	Remarks
Crash-Related Incidents		
Vehicle collision (any type)	Potential Fatality/Injury	Requires EMS, police, and forensic response; high-priority dispatch
Overtaken truck / large vehicle	Potential Fatality/Injury/Queue Build-up	Requires EMS and police response; risk of blockage or extended congestion
Vehicle fire or smoke	Potential Fatality/Injury	Requires EMS, fire service, police, and forensic support; high-priority emergency dispatch
Pedestrian struck (if observed)	Potential Fatality/Injury	Requires EMS and police response; priority based on visual cues or crowd reaction
Minor vehicle contact/fender bender	Minor / Queue Build-up	Requires basic EMS response or police presence; TMC to monitor for congestion impact; possible outpatient care
Non-Crash Emergency Incidents		
Fire or smoke from roadside or vehicle (no crash)	Major	Requires fire service and EMS dispatch; potential evacuation and lane closure
Environmental hazard (flooding, storm, dense fog)	Intermediate / Major	Requires RWIS alert and TMC coordination with Bangladesh Meteorological Department (BMD); dispatch based on severity and visibility impact
Vehicle stopped in moving lane (no crash)	Intermediate	Requires police or service patrol dispatch; potential traffic obstruction
Disabled vehicle or illegal stop on shoulder	Minor	Requires service patrol dispatch; typically, low-risk clearance
Dropped object on the road	Minor / Intermediate	Requires service patrol; response urgency based on lane impact and object type
Queue formation or extended congestion	Intermediate	Requires police or civil authority response; may trigger congestion management protocols like alternate route information
Crowd movement/road blockage by people	Intermediate	Requires police or civil authority response; hazard depends on location and crowd behavior

7.36.2.3. Structured Data Collection and Reporting for Emergency Management System (EMS)

A structured data collection and reporting framework is essential for monitoring Emergency Management System (EMS) operations, assessing performance, and identifying systemic

improvements in incident response and roadway clearance processes. The following section outlines the required data parameters, key time metrics, and incident classification models to support informed decision-making and continuous service optimization.

Emergency Data Collection Parameters

Numerous global studies indicate that the “Golden Hour”, the first hour following a serious road traffic injury, is the most crucial period during which timely medical intervention significantly improves the chance of survival and reduces the severity of long-term disability. Again, delays in incident detection, verification, or dispatch of emergency responders can result in preventable fatalities, prolonged roadway disruptions, and increased risk of secondary crashes. Hence, a structured time-tracking mechanism embedded within EMS operations is essential for continuous performance evaluation, outcome-driven planning, and optimal allocation of emergency resources. The structured data collection shall be standardized based on the incident timeline as shown in Figure 7.36-1.

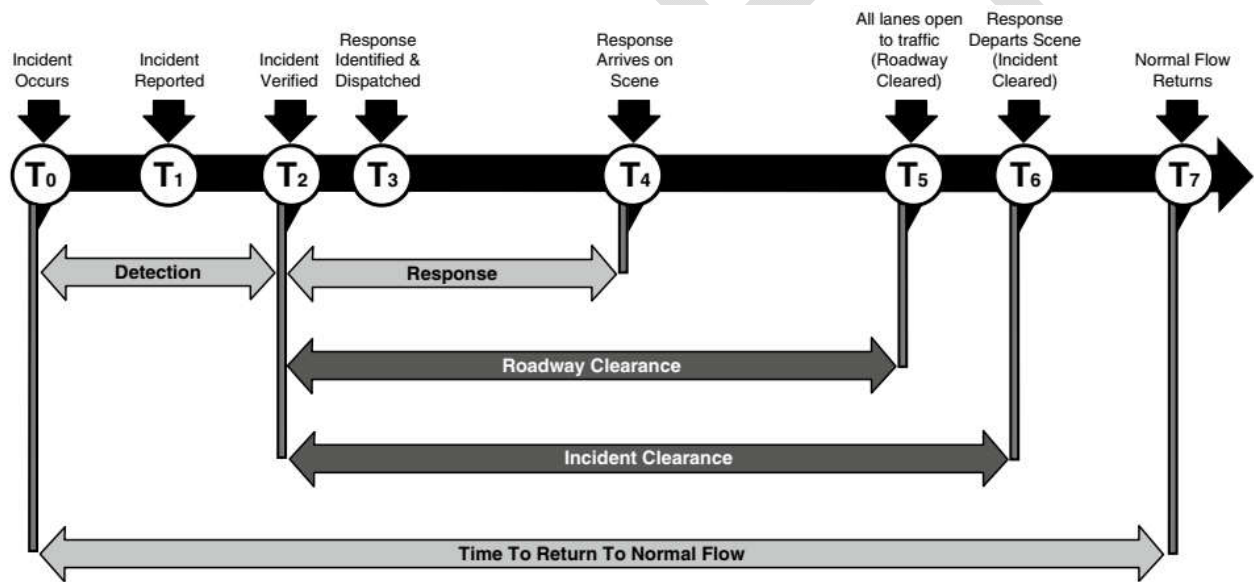


Figure 7.36-1: Timeline for emergency incident management (Gordon, R., 2015).

Table 7.36-2: Key Incident Times (adapted from (Gordon, R., 2015)).

Incident Phase	Duration	Definition
Detection time	$T_1 - T_0$	The time between the incident occurring and the incident being reported. Detection time is typically not reported because the actual time the incident occurred is often unknown.
Verification time	$T_2 - T_1$	The time between the incident being reported and the incident being verified.

Response time	$T_4 - T_2$	The time between the incident being verified and the responder arriving on the scene. Law enforcement may not be the first party to arrive. Response time depends on the incident location and each responding party's proximity to the incident.
Roadway clearance time	$T_5 - T_1$	The time between the first incident report and the first confirmation that all lanes are available for traffic flow.
Incident clearance time	$T_6 - T_1$	The time between the first incident report and the time that the last responder left the scene.

The following parameters shall be recorded for each emergency incident:

Table 7.36-3: Key Parameters for Structured Emergency Incident Data Collection.

Parameter	Description
Roadway Section ID	Unique identifier for the location of the incident
Incident ID	Unique identifier assigned to each incident
Roadway Direction	Direction of travel (e.g., Northbound, Southbound)
Date	Date of incident occurrence
Time Incident Detected (T_1)	Time at which the incident was first reported or observed
Time Response Arrived (T_4)	Time at which emergency responders arrived at the scene
Time Roadway Cleared (T_5)	Time at which traffic lanes were made fully operational
Time Incident Cleared (T_6)	Time at which all responders left the scene
Type of Incident	Accident or non-accident
Incident Location Type	Shoulder or moving lane
Number of Lanes Closed	Count of lanes affected by the incident
Duration of Lane Closure	Total time (in minutes) that one or more lanes were closed
Detection Time ($T_1 - T_0$)	Time between incident occurrence and first report
Verification Time ($T_2 - T_1$)	Time between first report and official verification
Response Time ($T_4 - T_2$)	Time between verification and responder arrival
Roadway Clearance Time ($T_5 - T_1$)	Time between first report and full lane availability
Incident Clearance Time ($T_6 - T_1$)	Time between first report and complete scene clearance

A composite summary of reported incidents shall be maintained for operational evaluation. Table 7.36-4 presents a representative profile based on historical patterns:

Table 7.36-4: Composite profile of reported emergency incidents by type (adapted from (Gordon, R., 2015)).

Category	Type	Location	Share (%)	Average Response Duration (min)	Average Roadway Clearance Time (min)
Recorded Incidents (70%)	Disablements	Shoulder	80%	15–30	30–45
		Blocking Lanes	20%	15–30	60–90
	Accidents	Shoulder	60%	45–60	90–120
		Blocking Lanes	40%	45–90	120–180

	Other	Shoulder	70%	15–30	30–45
		Blocking Lanes	30%	30–45	60–90
Unrecorded Incidents (30%)	—	—	—	—	—

Several other formats can be followed, suited to the emergency incidents, at the discretion of the Engineer.

7.36.2.4. Emergency Incident Command System (ICS) Integration

To ensure coordinated and efficient incident response, the Emergency Management System (EMS) shall adopt an Incident Command System (ICS) framework, facilitating multi-agency operations with standardized roles, interoperable communication, and integration with ITS subsystems.

Table 7.36-5 summarizes the alignment of core EMS functions with incident management phases under ICS. It outlines how detection, response, clearance, and recovery actions are coordinated across agencies through TMC-led command protocols.

Table 7.36-5: EMS functional alignment with ICS phases (adapted from (Gordon, R., 2015)).

Emergency Incident Management Function	Detection and Verification	Response	Clearance	Recovery
Coordinate development, archiving, and update of incident response plans	✓	✓	✓	✓
Integrate traffic incident management needs into operations planning and ITS design	✓	✓	✓	✓
Detect an incident and identify its properties (lanes blocked, location)	✓			
Classify the incident into type and severity	✓			
Notify responding agencies of the location and character of the incident	✓			
Select a response plan. Implement:		✓	✓	✓
• Lane and ramp controls				
• Emergency signal timing plans				
• Motorist information				
Facilitate operations for emergency responders		✓	✓	✓
Provide traffic conditions and/or route guidance to emergency responders		✓	✓	✓
Provide incident information to motorists		✓	✓	✓
Provide tail of the queue detection		✓	✓	
Terminate incident management functions				✓

Table 7.36-5 presents the ITS technologies and operational support mechanisms that enable each phase of emergency incident management including detection, classification, response execution, responder

assistance, tail-of-queue detection, and incident recovery through coordinated use of systems such as CCTV (manual monitoring), VIDS, ASES-SS, RWIS, 999 services, TMC displays, highway police, service patrols, and in-vehicle responder guidance tools.

Table 7.36-5: ITS and operational technology support for EMS incident management (adapted from (Gordon, R., 2015)).

Operations and Technologies	Incident Detection and Verification	Incident Classification	Response Plan Implementation	Emergency Responder Operations	Traffic Information for Emergency Responders	Tail of Queue Detection	Termination of Incident Management
CCTV	✓	✓	✓	✓	✓	✓	✓
VIDS	✓	✓	✓	✓	✓	✓	✓
ASES-SS	✓	✓	✓	✓	✓	✓	✓
RWIS	✓	✓	✓	✓			✓
999 service	✓	✓			✓		
RHD iMAP responders	✓	✓			✓		
Highway Police services patrols	✓	✓	✓	✓			
TMC information displays	✓	✓	✓				
VMS			✓				
Lane controls			✓				
Surveillance and travel time on alternate routes			✓		✓		
Traffic information for emergency service providers					✓		
In-vehicle information for emergency providers					✓		

7.36.3. Operational Requirements

7.36.3.1. Operation and Management of 24/7 Ambulance Services

A key component of the Emergency Management System (EMS) is the continuous operation and management of ambulance services to ensure timely medical response and safe transport of patients from incident locations to designated healthcare facilities. The ambulance fleet shall be managed to provide 24/7 service coverage, with each unit staffed by trained Emergency Medical Technicians

(EMTs) and supported by functional protocols that prioritize patient safety, response efficiency, and seamless coordination with other EMS subsystems.

The service provider shall be responsible for the recruitment and deployment of qualified drivers and EMT paramedics who possess relevant certification and experience in emergency response. Comprehensive training programs shall be developed and delivered in collaboration with nationally recognized health authorities. These programs must cover pre-hospital care, emergency driving procedures, medical equipment usage, and communication protocols aligned with EMS software and dispatch systems. Refresher trainings shall be conducted periodically to maintain operational competence.

Each ambulance shall be equipped with essential medical supplies and devices, including oxygen delivery systems, ambu bags, basic monitoring tools, and communication equipment. First Aid Kits, as defined in the relevant specification section, shall be supplied and replenished regularly. Staff shall be provided with appropriate personal protective equipment (PPE) to ensure infection control and personal safety during patient handling.

The operational responsibility also includes vehicle maintenance, fuel management, and insurance coverage. Ambulances must undergo scheduled servicing to ensure mechanical reliability and hygiene standards, and all deployed units must remain roadworthy, insured, and ready for immediate dispatch. Fleet deployment must follow a strategic pattern to maximize coverage and minimize response time. Daily operational oversight shall be maintained by designated personnel responsible for monitoring shifts, verifying service logs, and ensuring protocol compliance.

Ambulances shall be fully integrated into the EMS platform, allowing real-time tracking, automated dispatch, and seamless communication with the Traffic Management Center (TMC) and call center operations. Dispatch responses shall be logged and monitored, with performance evaluated based on response time, incident outcomes, and system uptime.

7.36.3.2. Operation and Management of Bike Ambulance Services

To complement ambulance services, the EMS framework includes bike ambulance operations designed for rapid medical intervention in areas with access constraints or high congestion. These units are intended to deliver Basic Life Support (BLS) and initial stabilization at the scene prior to the arrival of a full-service ambulance.

Bike ambulances shall be operated by certified EMTs or paramedics trained specifically for urban and high-density response scenarios. Personnel shall be recruited based on their ability to safely operate two-wheeled vehicles and administer emergency medical care. All operators must undergo structured

training on emergency response procedures, safe riding practices, on-site triage, and coordination with EMS dispatch and call center systems.

Each bike ambulance shall be equipped with a compact and essential medical kit, including a portable oxygen cylinder, ambu bag, blood pressure apparatus, cervical collar, and a standard First Aid Kit as defined in the EMS specification. Communication tools such as mobile phones with EMS applications and Bluetooth intercom-enabled helmets shall be provided to facilitate real-time updates and dispatch coordination.

Deployment infrastructure shall be established to support the efficient operation of bike ambulances. This includes maintenance sheds and parking stations located strategically to ensure that a responder can reach any incident location within a defined target response time. Vehicles must be maintained to high mechanical and hygiene standards, with fuel availability, tire condition, and signaling systems regularly inspected.

Operational oversight shall include the assignment of supervisory personnel to manage dispatch tracking, performance logging, and coordination with the broader EMS network. Each response shall be documented within the EMS platform to support performance monitoring and ensure accountability.

7.36.3.3. Operation and Management of Non-Crash Emergency Services

In addition to post-crash medical response, the Emergency Management System (EMS) shall encompass the operation and management of non-crash emergency events that impact roadway safety, mobility, and user welfare. These include, but are not limited to, fire outbreaks, flooding, dense fog, hazardous material spills, infrastructure failures, stalled vehicles in live lanes, extended congestion, and obstruction by crowds or debris.

Non-crash emergency management shall be integrated into the broader EMS operational framework, using data feeds from ITS subsystems such as the Road Weather Information System (RWIS), Video Incident Detection Systems (VIDS), and input from field personnel or emergency hotlines. Events shall be verified through multi-source validation including camera feeds, sensor thresholds, or reports from police and service patrols.

A standard operating protocol shall be established for each category of non-crash emergency, aligned with national disaster preparedness and road operation guidelines. EMS response units shall be mobilized based on event type and severity. This may include ambulance deployment in health-impacting scenarios (e.g., smoke or hazardous gas), coordination with fire services, road clearance crews, or police for crowd control and infrastructure protection.

Each reported event shall be logged into the EMS software platform, with detailed time-stamped records of detection, verification, response initiation, field actions taken, and clearance. Where applicable, variable message signs (VMS), SMS alerts, or TMC-controlled mobile apps shall be used to disseminate warnings or detour instructions to the public.

Routine drills and scenario-based response simulations shall be organized to train personnel, including EMS teams, traffic police, volunteers, and dispatchers, on coordinated management of non-crash emergencies. Key performance indicators (KPIs) such as response time, clearance duration, and incident recurrence shall be tracked for continuous system improvement.

Responsibility for the operation and management of these services shall lie with the designated EMS contractor, in coordination with relevant authorities such as the Highway Police, Fire Service, Civil Defense, meteorological agencies, and the local government engineering department. Strategic planning for high-risk zones, weather-prone areas, and crowd-sensitive segments shall guide the deployment of response resources.

All such non-crash emergency operations must maintain interoperability with the core EMS dispatch system, incident logbook, and reporting modules to ensure transparency, accountability, and centralized situational awareness across the highway network.

7.36.3.4. Call Center Operations and Bystander Care Coordination

The EMS call center serves as the central hub for incident reporting, responder dispatch, and volunteer coordination. Operating 24/7, the call center shall be fully integrated with the EMS software system and capable of managing real-time communication across ambulance fleets, bike ambulances, trained volunteers, hospitals, and enforcement agencies.

The service provider shall design and implement a crash response and communication management system to facilitate structured call handling, dispatch prioritization, and service tracking. Standard Operating Procedures (SOPs) shall be developed to guide incident assessment, triage categorization, ambulance deployment, and communication with relevant stakeholders. These SOPs must reflect national emergency health care protocols and ensure consistency across all incidents.

Recruitment of call center personnel shall prioritize individuals with strong communication skills and an understanding of emergency service operations. All staff shall be trained in emergency response procedures, software tools, data logging, and inter-agency coordination. Training must also cover system features such as real-time tracking, call prioritization, and interaction with the Bystander Care Volunteer Network.

The call center platform must include automated data capture, incident logging, and dashboard tools for operational analytics. Features such as call recording, ticketing, performance metrics, and incident closure time tracking must be implemented to support quality assurance and training. Real-time alerts and notifications to nearby volunteers shall be supported through a dedicated app interface, with two-way communication enabling guidance and follow-up during on-site intervention.

Medical oversight shall be incorporated into the call center operations to ensure that emergency triage and medical instructions align with national pre-hospital care standards. Performance monitoring shall be embedded into daily operations, supported by analytics dashboards and periodic reporting aligned with defined Key Performance Indicators (KPIs).

7.36.3.5. Training and Capacity Building for EMS Personnel and Volunteers

Training is a core functional element of the Emergency Management System (EMS), designed to ensure that all human resources involved in emergency response, including professional staff and community-based volunteers, are adequately prepared to deliver timely, effective, and coordinated pre-hospital care. The training component shall be implemented prior to the commencement of services and maintained through structured refresher cycles.

The service provider shall be responsible for developing and conducting comprehensive training programs tailored to the distinct roles and responsibilities of Emergency Medical Technicians (EMTs), ambulance drivers, call center operators, and bystander care volunteers. All training curricula shall be developed in consultation with relevant health authorities and experts in pre-hospital care.

Training for Medical Personnel and Drivers

All EMTs operating on ambulances and bike ambulances shall receive training focused on Basic Life Support (BLS), trauma response, use of emergency medical equipment, and field communication protocols. Similarly, ambulance drivers shall undergo instruction in primary healthcare, safe and efficient navigation to incident sites, and coordination with dispatch centers. Each training batch shall include no more than 30 participants, with a core training duration of two (2) days. Refresher training shall be conducted every twelve (12) months for all medical personnel and drivers, with a one-day program focused on protocol updates, performance review, and field challenges.

Training for Call Center Operators

Call center operators shall be trained in emergency communication protocols, EMS software usage, incident triage classification, caller interaction, and coordination with ambulances, bike units, and volunteers. Training shall emphasize situational judgment, system responsiveness, data accuracy, and inter-agency communication. The initial training program shall be two (2) days in duration and shall

include simulation-based exercises. Operators shall also be included in periodic refresher sessions every 18 months to maintain operational standards and service quality.

Training for Bystander Care Volunteers

The bystander care component is vital for rapid, community-level intervention before formal EMS units arrive. Each volunteer pair shall be provided with a first aid kit and a foldable stretcher to support immediate response activities. Training shall be delivered in batches of 30 participants over two (2) days, spaced 7 to 10 days apart to accommodate community schedules and logistical coordination. Volunteer training shall cover basic trauma care, bleeding control, CPR, scene safety, victim handling, and coordination with call centers and responders.

Volunteers shall undergo refresher training every six (6) months, with each session lasting two (2) days. These sessions shall serve as both technical refreshers and performance evaluation forums. The service provider shall organize a formal recognition ceremony during each refresher cycle to acknowledge the top-performing volunteers and incentivize community participation.

Training Logistics and Support

The service provider shall be fully responsible for all training logistics, including venue arrangement, training materials, medical equipment demonstrations, food, and hospitality. Digital and printed training manuals shall be distributed to all participants. A dedicated Training Manager and a team of supervisors shall oversee planning, execution, attendance tracking, and feedback collection in compliance with applicable national outsourcing guidelines.

7.36.4. Technical Specification for Standard Ambulance with Emergency Health Care System

The Standard Ambulance shall be a fully equipped Basic Life Support (BLS) unit designed for the transport and pre-hospital stabilization of patients. It shall conform to international standards such as EN 1789:2020, AIS 125 Part 1, or equivalent, and be operationally integrated with the EMS Fleet Management System.

Vehicle Base

Feature	Specification
Chassis Type	Factory-built or OEM-modified ambulance van (e.g., Toyota Hiace, Ford Transit, or equivalent)
Fuel Type	Diesel or CNG (Euro IV or higher emission standard)
Transmission	Manual or Automatic, min. 5-speed

Drive Configuration	2WD or 4WD, depending on terrain needs
Engine Power	Minimum 2500cc or equivalent torque output
Cabin Capacity	Driver + 1 medical assistant (front); minimum 2 personnel + 1 patient in rear
Air Conditioning	Separate AC unit for patient and driver compartments
Suspension	Reinforced suspension suitable for smooth patient transport
Braking System	ABS with Emergency Brake Assist (EBA)

Interior Layout and Fixtures

Feature	Specification
Flooring	Non-slip, antibacterial vinyl flooring, washable
Partition Wall	Transparent sealed partition between the driver and the patient cabin
Interior Lighting	Medical-grade LED overhead lights and reading lights
Seating	Foldable paramedic seat with seatbelt; bench seat with storage
Cabinetry	Aluminum or composite modular cabinets with a secure latch system
Stretcher	ISO-certified collapsible wheeled stretcher with locking mechanism
Oxygen Cylinder Holders	Mounting for two (02) standard medical oxygen cylinders with regulator

Emergency Healthcare Equipment

Equipment	Specification
Oxygen Delivery System	Two 10-liter medical-grade aluminum cylinders with a flowmeter and humidifier
Ambu Bag (BVM)	Adult and pediatric sizes, silicone, reusable, with masks
Spine Board & Cervical Collars	Longboard with immobilization straps; small, medium, large collars
Suction Unit	Portable or built-in electric suction with a vacuum bottle
Defibrillator (Optional)	Semi-automated external defibrillator (AED)
Vital Signs Monitor	Optional; NIBP, SpO2, ECG, temperature
BP Apparatus & Stethoscope	Manual sphygmomanometer and dual-head stethoscope
First Aid Kit	Each unit shall be equipped with a complete First Aid Box as per Section 7.36.6, including monthly replenishable items and annual equipment as specified for BLS Ambulance
IV Kit	IV stand, cannulas, giving sets, tourniquet straps
Sanitization	Hand sanitizer, disposable gloves, sharps disposal container, trash bin with lid
Fire Extinguisher	Minimum 2kg ABC type with vehicle mounting

Electrical and Safety Systems

System	Specification
Inverter	1000W pure sine wave inverter with deep-cycle backup battery
Power Sockets	At least 3 internal 12V DC and 220V AC outlets

Communication	Two-way radio or mobile data terminal compatible with the EMS dispatch system
Emergency Lighting	Roof-mounted LED light bar (red/blue), siren, rear work lights
Camera System	Rear-view camera and cabin CCTV (optional, for dispatch integration)
Ventilation	Roof-mounted exhaust fan and fresh air intake system
Fire & Electrical Safety	Fuse-protected circuits, safety cutoff switch, fire blanket

Fleet Management and EMS Integration

Feature	Specification
GPS Tracker	Real-time GPS with SIM/GPRS data transmission to EMS server
Temperature Sensor	Cabin ambient temperature sensor linked to vehicle telematics
Buzzer Alert System	Integrated system for alerting the driver upon dispatch notification
Mobile App Integration	EMS Android/iOS app installed on a mounted tablet or phone
Driver Console	Touchscreen display for trip assignment, navigation, and status update
Data Logging	Trip duration, fuel logs, and patient pickup/drop timestamps are automatically logged

Warranty and Maintenance

Requirement	Specification
Warranty	Minimum 2 years vehicle + 1-year medical equipment
Service Support	Nationwide OEM or vendor network for preventive and corrective maintenance
Documentation	Complete user manuals for vehicle and medical equipment; maintenance schedule logbook
First 2 Years	Routine service covered by supplier (parts + labor)
Post-2 Years	Service provider to manage fuel, tires, maintenance, and insurance

7.36.5. Technical Specification for Bike Ambulance with Emergency Healthcare System

The Bike Ambulance shall be a single-responder motorcycle fitted with medical-grade emergency response kits and tracking equipment. It is intended for first response, initial stabilization, and scene assessment, particularly where larger ambulances cannot reach quickly due to traffic congestion or narrow access roads.

Vehicle Base

Parameter	Specification
Make/Model	Branded 150cc–200cc motorcycle (e.g., Hero Xpulse 200, TVS Apache, Bajaj Pulsar NS160, or equivalent)
Engine	Min. 150cc, 4-stroke, air-cooled, BS-VI compliant
Transmission	5-speed manual
Fuel Type	Petrol
Fuel Tank Capacity	≥10 liters

Top Speed	Min. 80 km/h
Drive Configuration	2-wheeler, standard configuration
Braking System	Front disc, rear drum, or ABS (preferred)
Payload Capacity	≥ 150 kg (rider + equipment)
Suspension	Dual-terrain with telescopic front and mono-shock rear
Battery	12V maintenance-free with auxiliary power connector

Medical Equipment Kit (Optimized for Bike Ambulance Use)

Equipment	Specification
Oxygen Cylinder	2–3L portable medical-grade aluminum cylinder with flowmeter, nasal cannula & face mask
Ambu Bag (BVM)	Adult-size, silicone, reusable, with mask
BP Apparatus & Stethoscope	Manual sphygmomanometer and dual-head stethoscope
First Aid Kit	<i>Each bike ambulance shall be equipped with a complete First Aid Kit as per Section 7.36.6, containing monthly replenishable supplies and annual equipment as specified for bike-based EMS response.</i>
Cervical Collars	Small and medium-sized adjustable collars (1–2 units max, based on space)
Thermal Emergency Blanket	Compact, foil-type emergency rescue blanket
Minimal IV Kit	One set of IV cannula (18G–22G), giving set, adhesive tape, and tourniquet
LED Torch Light	Rechargeable flashlight with ≥8 hours backup
Documentation Kit	Patient logbook or EMS app-enabled digital data entry device

Medical Storage and Mounting System

Component	Specification
Storage Boxes	Dual side-mounted, weatherproof FRP or aluminum alloy boxes, 60–80L total capacity
Mounting	Vibration-resistant bolting to frame; balanced distribution
Visibility	Reflective striping and high-visibility decals on boxes and vehicle bodies
Weight Balance	Equal weight distribution left/right to preserve stability during operation

Electrical and Signaling System

Item	Specification
Siren and Beacon	Compact red/blue LED beacon with dual-tone siren; handlebar-mounted switch control
Auxiliary Power	USB charging port for mobile phone/app device
Backup Battery (Optional)	6Ah Li-ion backup battery for medical devices
Communication	Mobile phone with EMS dispatch app + Bluetooth headset (in helmet)

EMS System Integration

Functionality	Specification
GPS Tracking	Real-time GPS/GPRS module integrated with EMS dispatch system
Mobile EMS App	Android-based app pre-installed on the rider's device
Dispatch Alert System	Audible buzzer or phone vibration alert for new call reception
Trip Logging	Automatic or manual status updates: en route, on scene, incident closed

Personnel and Safety Equipment

Item	Specification
Helmet	Full-face ISI-certified with integrated Bluetooth headset
Rider Gear	High-visibility EMT vest with reflective tape and ID pocket
Fire Extinguisher (Optional)	1kg ABC-type secured in the left storage box
Tool Kit	Puncture repair kit and multi-tool set included

Maintenance and Servicing

Responsibility	Specification
Routine Maintenance	Engine, brake, chain, tire checks every 1,000 km
Medical Equipment Check	Monthly inventory and oxygen refill (twice/month)
Spare Parts	Availability guaranteed for 2 years from supply
Logbook	Digital or paper maintenance and dispatch log required for each unit

7.36.6. Contents of the First Aid Box

A. Regular Medical Supplies

Item No.	Item Name	Specification / Use	Qty per Kit
1	Roller Bandages (4" x 4")	Standard gauze for dressing wounds	200 units
2	Soft Roll Bandages (4" x 4")	Soft gauze for secure wrap	50 units
3	One-Time Bandages	Adhesive strips for small cuts	100 pieces
4	Hexisol (large)	Antiseptic hand and skin disinfectant	4 units
5	Surgical Cotton Roll (Large)	For dressing support and packing	20 units
6	Anesthesia Spray	Surface anesthesia for pain relief	1 unit
7	Povisept (Antiseptic)	For wound disinfection	4 units

8–10	Cervical Collars (Small, Medium)	Neck stabilization (1 each)	3 units total
11	Sterile Gauze Bandages (4" x 4")	For dressing open wounds	12 units
12	Sterile ABD Pads (5" x 9")	Heavy-duty absorbent dressings	6 units
13	Sterile Kerlix Gauze Rolls (4")	Wrap around other dressings	6 units
14	Plastic Adhesive Tape (1")	Waterproof medical-grade tape	2 rolls
15	Nitrile Gloves (Box)	Hypoallergenic, powder-free	Box of 100
16	Trauma Shears	Blunt-nosed scissors for cutting	1 unit
17	Hand Sanitizer (250 ml)	Hand hygiene	2 bottles
18	Wooden Dowels	For splinting and tourniquet	20 cm (tourniquet), 50 cm & 100 cm (splinting) – labeled
19	Irrigation Water Bottle	Sterile or boiled water	1 bottle
20	First Aid Backpack or Box	Green with white cross (Geneva compliant)	1 unit
21	Tarp / Plastic Sheet	To protect patient/vehicle surfaces	1 unit
22–24	Cervical Collars (All sizes)	For pediatric and adult immobilization	3 total
25–26	Cloth Strips for Tourniquet	Red: Adult / Green: Child/splint tie	6 red + 6 green

B. Additional Equipment (Ambulance-Specific)

Item No.	Item Name	Specification / Notes	Supply Frequency
27	Torch Light	Rechargeable LED, ≥ 8 hrs backup	1 per year
28	IV Cannula	18G–22G mixed sizes	10 units per month
29	Oxygen Cylinder Refill	2L or 10L BLS-certified	Twice per month
30	Oxygen Mask	Adult/pediatric with tubing	4 per year
31	Ambu Bag (BVM)	Silicone, reusable, standard size	2 per year
32	BP Machine & Stethoscope	Manual; dual-head	2 sets per year
33	Stretcher	Foldable or fixed; used for patient transfer	1 per ambulance

C. Packaging and Labelling

- All items must be pre-packed in a compartmentalized, waterproof backpack or box
- Each item must be labelled in Bangla and English, with expiry dates where applicable
- Sharp or fragile items (e.g., shears, glass bottles) should be placed in shock-absorbing pockets

D. Quality and Compliance Requirements

Category	Requirement

Medical Grade	All dressings, gloves, and devices must be CE/FDA/ISO 13485 certified
Chemical Products	Must be approved by the Directorate General of Drug Administration (DGDA), Bangladesh
Packaging	Dustproof, moisture-resistant, tamper-proof packaging
Storage	Kits must withstand temperatures up to 45°C and high humidity

7.36.7. Personnel Requirements

To ensure uninterrupted, round-the-clock delivery of EMS services across all system components, including ambulance deployment, bike ambulance operation, call center functionality, field response, and central coordination, the Service Provider shall deploy the following minimum personnel. These staff shall be distributed across field posts, ambulance units, and the Traffic Management Center (TMC) /Call center in accordance with service area coverage and shift rotation needs.

Table 7.36-6: Minimum manpower requirements for EMS operations.

SL	Position	Minimum Number Required ²¹	Remarks
1	Team Leader (National/regional Operations)	1	Overall EMS program lead; single point of accountability
2	Operations Manager	1	Field and dispatch oversight; reports to Team Leader
3	Supervisors	20	Field coordination, shift management, response monitoring
4	Ambulance Drivers (BLS)	100	One per BLS ambulance per shift (minimum 2-shift rotation)
5	Medical Assistants / Paramedics (BLS)	100	One per BLS ambulance per shift (minimum 2-shift rotation)
6	Bike Ambulance Operators (EMT/Nurse)	50	One per-bike ambulance per shift
7	Call Center Operators	15	Distributed across three (03) shifts (5 per shift)
8	Accountant	1	Finance, payroll, and budgeting
9	Statisticians / Data Analysts	2	Reporting, dashboard analytics, KPI tracking
10	Office Assistants	4	Support logistics, supplies, and documentation
11	Bystander Care Volunteers	1,200	Organized in pairs; assigned across service corridors

²¹ These numbers are indicative only.

7.36.8. EMS Software System

The Emergency Management System (EMS) software shall be a comprehensive, integrated, and modular digital platform designed to support real-time coordination, tracking, dispatch, and reporting of emergency medical services, including ambulances, bike ambulances, call centers, and bystander care operations. The system shall be capable of handling high-volume emergency scenarios, integrating vehicle telematics, and supporting a 24/7 call center across distributed locations.

Core System Architecture

The EMS software shall consist of the following layers:

- **Backend Core Services:** Microservices-based backend architecture using a secure RESTful API framework to support modular scalability and integration.
- **Relational Database:** Oracle RDBMS with a perpetual license, supporting structured storage of all operational, vehicle, patient, and call data.
- **Middleware & API Layer:** Service Gateway for internal component communication and third-party integrations.
- **Frontend Layers:**
 - **Web-Based Control Panel** for administrators and call center operators
 - **Mobile Application** for ambulance drivers, paramedics, and field volunteers
- **Cloud Hosting:** Deployed on a Government of Bangladesh (GOB) cloud data center with disaster recovery (DR) provisions in a secondary GOB-owned facility.

Functional Modules

Fleet and Ambulance Management

- Real-time **GPS tracking** for all ambulances and bike units.
- Automated **route optimization** using traffic-aware APIs (Google Maps or OpenStreetMap SDK).
- **Trip assignment logic** based on location proximity, duty status, and estimated arrival time (ETA).
- Integration with **vehicle sensors**: temperature monitoring, door-open sensors, buzzer alert systems.
- **Resource utilization analytics**: mileage, fuel consumption, idle time, engagement time.
- **Vehicle readiness logs**: maintenance history, duty hours, shift rosters.

Emergency Call Center Management

- Full-featured **Computer-Aided Dispatch (CAD)** system for call logging, prioritization, and ambulance dispatch.
- Real-time **dashboard** for monitoring call volume, waiting time, assignment lag, and call status (open/closed).

- **Call ticketing system** with auto-populated forms, timestamps, and incident ID generation.
- Integration with a **buzzer/alert system** for notifying the nearest ambulances and drivers.
- Voice call log, **call recording**, and **audio analytics** for quality control.
- **Volunteer-based interface** for registering emergency calls and preliminary incident information.
- Web-based **role-based access panels** with alert levels and escalation workflows.

Navigation and Time Estimation Module

- In-app routing with embedded Map SDK (no redirection to third-party apps).
- ETA calculation for:
 - Ambulance to incident site
 - Incident site to hospital
- Live **incident map visualization** and traffic-aware detour suggestions.
- Automated **hospital recommendation** based on capacity, proximity, and service type.

Mobile Applications

- **For Drivers/EMTs:**
 - Trip alert pop-up with location and estimated travel time
 - Dynamic route updates
 - Vehicle readiness checks
 - Buzzer and temperature alerts display
- **For Call Handlers and Field Volunteers:**
 - Emergency call logging
 - Incident status tracking
 - On-site action logs with time-stamping
- Offline data sync capability
- 2-Factor Authentication (2FA) for login

Web Application & Control Center Interface

- **Live system dashboard** with color-coded ambulance status indicators
- **Incident heatmaps** and real-time location plotting
- User management (admin/operator/volunteer)
- Ambulance registry, hospital registry, volunteer registry
- Configurable incident forms and SOP workflows
- Analytics module for:
 - Average response time
 - Ambulance performance
 - Shift utilization
 - Call center load and occupancy rates
- Exportable reports in CSV/XLS/PDF

Hosting and Security Requirements

- Hosted in GOB-owned data center with DR backup.
- Full **end-to-end encryption** for data in transit and at rest (TLS 1.3, AES-256).
- Role-based access control (RBAC) with user groups, permissions, and audit trail.
- Web and app login with **two-factor authentication**.
- Firewall, **Intrusion Detection System (IDS)**, and traffic anomaly detection.
- Compliance with:
 - National data protection laws
 - OWASP Top 10 application security practices
 - API gateway protection against DDoS and malicious actors

Maintenance, Support, and Training

- **24/7 technical support** hotline and issue resolution within 1 hour.
- **99% system uptime** ensured via load balancing and server redundancy.
- Full documentation of:
 - Source code
 - Database schema
 - API usage
 - Admin guides and training manuals
- **Training of 40 designated government officials** on system use and management.
- Quarterly software updates and bug patching.
- Maintenance and support commitment for **5 years** post-deployment.

Intellectual Property Rights (IPR)

To ensure sovereign control, long-term maintainability, and national customization of the EMS platform, all intellectual property rights associated with the developed software shall be vested exclusively with the Roads and Highways Department (RHD). This includes ownership of all source code, trained AI/ML models, configuration files, user interfaces, and any related documentation developed under the contract.

Key Performance Indicators (KPIs)

- **System Uptime:** $\geq 99\%$
- **Issue Response Time:** ≤ 1 hour
- **GPS Accuracy:** ≤ 10 feet
- **Call Assignment Time:** ≤ 2 minutes average
- **Incident Log Completeness:** 100% for all dispatched cases
- **Volunteer Data Capture:** $\geq 90\%$ of incidents with volunteer response

7.36.9. Measurement

The measurement of the **Emergency Management System (EMS)** shall encompass the satisfactory delivery, deployment, and commissioning of all specified functional components, systems, and services defined under this section. The prices of the items shall include the design, supply, installation,

integration, testing, commissioning, operation, and maintenance of EMS infrastructure, vehicles, software, training, and support services as detailed herein.

The EMS software system, including the Fleet Management System, Call Center Management Platform, Mobile Applications, and Web Dashboard, shall be measured upon complete system installation, user access provisioning, functional integration with TMC and ITS components (VIDS, ASES-SS, RWIS), and verification of all core modules (dispatch, GPS tracking, analytics, reporting, incident management, ICS coordination, public alerts, etc.) in accordance with the technical specification. A certificate of functional acceptance signed by the Engineer shall serve as proof of completion.

The supply, registration, and commissioning of fully equipped **Standard BLS Ambulances** and **Bike Ambulances** shall be measured as a deliverable based on actual vehicle deployment and operational readiness. Each ambulance shall be verified for compliance with all technical, mechanical, and medical specifications, including GPS integration, First Aid kits, communications systems, and EMS application functionality. Measurement shall also include the setup of support infrastructure (bike sheds, maintenance points), vehicle insurance, and integration with the EMS platform.

Continuous operation of ambulance and bike ambulance services shall be measured through daily shift logs, GPS data, dispatch logs, and incident records showing vehicle engagement, medical interventions, and travel logs. Performance will be tracked against KPIs such as average response time, availability rate, vehicle downtime, and coverage area saturation. Payment will be made quarterly against certified logs and performance reports.

Measurement of the EMS call center shall be based on its establishment, integration with TMC and ITS systems, recruitment and deployment of trained call center staff, and full functionality of dispatch, tracking, ticketing, logging, and audio monitoring systems. Reports on call volume, response times, incident assignment, call closure rates, and compliance with SOPs shall be used to validate service delivery.

The Service Provider shall be responsible for the recruitment and deployment of required personnel, including EMTs, drivers, supervisors, statisticians, volunteers, and support staff. Measurement shall be based on submission of attendance sheets, training completion certificates, and field deployment reports. Refresher training shall also be monitored and measured on a semi-annual basis.

The deployment and activation of the bystander care volunteer network shall be measured based on the number of trained and active volunteers, provision of first aid kits and stretchers, and actual participation in emergency responses. Volunteer activation logs, training records, and incident response data will serve as the basis for measurement.

Measurement shall include verification of the delivery, inventorying, and periodic replenishment of first aid boxes as per the defined specification. The Engineer shall verify that each BLS ambulance, bike ambulance, and pair of volunteers is supplied with fully stocked kits, restocked monthly (or as per defined frequency), and labeled as per standard packaging requirements.

The hosting of the EMS system within Government-approved data centers and the provision of DR (Disaster Recovery) infrastructure shall be measured through successful data backup logs, security audit reports, and system availability statistics. Scheduled maintenance activities, bug fixes, and version updates shall also be documented and verified for measurement.

Performance reports covering key indicators such as system uptime, average response time, GPS accuracy, call closure rates, dispatch logs, and data completeness shall be submitted monthly. These reports shall be used for validation of service continuity and system effectiveness. Non-compliance or consistent underperformance shall result in pro-rata deductions as determined by the Engineer.

Final measurement shall include the submission of all required technical and operational documentation, including source code, API documentation, training materials, system design documents, and user manuals. This shall be verified against the deliverables listed in the contract. All system components must be fully handed over to the Employer prior to final acceptance.

7.36.10. Payment

Payment shall be made in accordance with the agreed milestone schedule included in the contract, with each milestone linked to measurable deliverables described above. Partial payments may be withheld for non-compliance, incomplete deployment, or performance deficiencies as determined by the Engineer.

The Service Provider shall ensure that all EMS components, hardware, software, and operational systems remain compatible with evolving international standards and technological updates throughout the contract period. Where higher-performing, more secure, or interoperable solutions become available, the equivalent upgrades shall be adopted, provided they do not alter the approved system architecture, subject to approval by the Engineer.

Pay items shall be subject to further breakdown and disaggregation as per actual implementation requirements and at the discretion of the Engineer. This may include adjustments in units, system configurations, deployment phasing, or integration modalities depending on site-specific conditions, system evolution, or stakeholder coordination protocols.

Pay items shall be:

Item No.	Description	Unit
7.36.1	Design, Development, and Deployment of EMS Software System (Including FMS, CAD, Mobile Apps, and Dashboard)	Lump sum
7.36.2	Supply and Commissioning of Standard BLS Ambulance Fully Equipped with EMS Integration	Lump sum
7.36.3	Supply and Commissioning of Bike Ambulance Fully Equipped with EMS Integration	Lump sum
7.36.4	Deployment of Central/Regional EMS Server and API Integration Layer	Lump sum
7.36.5	Hosting of EMS Software Platform with Disaster Recovery Infrastructure	Lump sum
7.36.6	Set up of Ambulance Maintenance Shed and Parking Bays	Per unit
7.36.7	Operation and Management of 24/7 Ambulance Service (BLS Units)	Per month
7.36.8	Operation and Management of Bike Ambulance Service	Per month
7.36.9	Supply and Maintenance of Medical Equipment for Ambulances and Bike Units	Per unit
7.36.10	Supply of First Aid Boxes for Ambulances, Bike Ambulances, and Volunteers	Per unit
7.36.11	Operation of 24/7 EMS Call Center	Per month
7.36.12	Recruitment and Training of EMTs, Drivers, and Call Center Operators	Per person
7.36.13	Training and Mobilization of Bystander Care Volunteers	Per person
7.36.14	Supply and maintenance of PPE, communication tools, and uniforms for EMS Personnel	Per person
7.36.15	Set up and maintenance of the Emergency Response and Monitoring Office	Lump sum

7.37. Electronic Toll Collection System (ETCS)

7.37.1. General

The Electronic Toll Collection System (ETCS), a core component of Intelligent Transportation Systems (ITS), is an advanced, automated solution designed to enable toll collection without requiring vehicles to stop at physical toll booths. This document outlines the technical specifications for the design, implementation, operation, and maintenance of a secure and interoperable ETCS. The system identifies and authenticates vehicles using technologies such as Radio Frequency Identification (RFID) tags and readers, Dedicated Short-Range Communication (DSRC) with onboard units (OBUs) and integrated circuit (IC) cards, smart cards, Automatic Number Plate Recognition (ANPR), and video-based vehicle classification. Once a vehicle is identified and verified, the applicable toll amount is automatically deducted from a linked account or prepaid balance, enabling seamless and uninterrupted travel by using the system. The system shall comply with BS EN ISO 17573-1:2019, TA 98/08 from the UK Highways Agency, and relevant FHWA and ISO standards. Key benefits include reduced

congestion, enhanced road safety, improved environmental sustainability, improved revenue collection efficiency, and support for scalable and nationwide tolling frameworks.

7.37.2. Toll Plaza Design Requirements for ETCS

7.37.2.1. Toll Collection Methods

Modern toll collection systems utilize a variety of methods designed to meet different levels of automation, traffic demands, and operational contexts. Toll collection methods can be broadly classified into three categories: Manual Collection, Semi-Automatic Collection, and Automatic Collection (ETCS).

Although there are several available methods for toll collection, it is recommended that, in order to give optimum flexibility in operational configuration, each toll lane is equipped to be capable of receiving payment by all of the chosen methods; although for normal operations, operators may choose to restrict some lanes to, for example, fully automatic (ETCS) or semi-automatic (card payment) system only.

Therefore, the toll plaza shall be designed to support a hybrid collection model. While several modes shall be accommodated, primary emphasis shall be placed on ETCS, with a certain percentage (say 50% or percentages decided by the Engineer in Charge) of lanes in each direction dedicated or convertible to ETCS only operation. Each lane shall support a minimum of two tolling modes to allow operational flexibility during peak demand or maintenance downtime.

The classification and detailed description of different toll collection methods shall be followed from chapter...: Intelligent Transport System of RHD Road Safety Engineering Manual 2024.

7.37.2.2. ETCS Technologies

Electronic Toll Collection Systems (ETCS) employ a suite of advanced technologies to enable seamless, automated tolling without requiring vehicles to stop. These systems combine wireless communication, video analytics, and intelligent sensing to ensure accurate vehicle identification and toll deduction. Among a variety of ETCS technologies (please see RHD Road Safety Engineering Manual 2024), the system in this Specification shall support the following technology tracks:

RFID-based toll collection system: The system shall be capable of implementing an RFID-based toll collection mechanism that utilizes passive Ultra High Frequency (UHF) RFID tags compliant with ISO/IEC 18000-63. Tags shall be affixed to the vehicle, typically on the windshield. As a vehicle passes through a tolling point, a fixed RFID reader mounted on a gantry or roadside pole shall detect the tag ID and transmit the information to the back-office system for account verification and toll

deduction. The system shall support basic tag authentication and vehicle matching against a centralized account database. Provisions shall be included for blacklisting defaulters, ensuring vehicles with outstanding dues are flagged at the toll point. This RFID-based solution shall be optimized for low-speed, urban, and semi-automated environments, offering a cost-effective and scalable deployment option.

DSRC-based tolling: The system shall support Dedicated Short-Range Communication (DSRC)-based tolling using On-Board Units (OBUs) installed on vehicle windshields or dashboards and Integrated Circuit (IC) cards containing user credentials. Roadside Units (RSUs) shall operate at a frequency of 5.8 GHz, enabling two-way encrypted communication between the vehicle and infrastructure. The IC card shall supply user and transaction data, and the system shall implement mutual authentication mechanisms to ensure secure processing. DSRC components shall comply with the following standards:

- EN 12253, EN 12795, and EN 12834 for DSRC protocols,
- ISO/IEC 14443 or ISO/IEC 7816 for IC card interfaces.

This configuration shall be applicable to high-speed tolling, expressways, and smart interchanges, ensuring reliable performance under dynamic traffic conditions.

ANPR and AVC tolling: The system shall be capable of implementing Automatic Number Plate Recognition (ANPR) and Automatic Vehicle Classification (AVC) technologies to support video-based tolling and vehicle enforcement. ANPR functionality shall be provided through dual-sensor cameras (infrared and visible light) with a resolution of at least 2 megapixels, and shall include Optical Character Recognition (OCR) capabilities for both English and local scripts. The ANPR system shall identify vehicles by license plate and cross-reference vehicle data with a backend registry for tolling, enforcement, or audit purposes. ANPR shall serve as both a primary and fallback method, particularly for non-tagged vehicles, mixed traffic, or violation detection scenarios.

To enhance classification accuracy, the system shall integrate Automatic Vehicle Classification (AVC), employing sensor types such as overhead IR/laser scanners, piezoelectric loops, and video-based classifiers. The AVC subsystem shall detect key vehicle attributes, including axle count, vehicle size, height, and profile. Video-based classification shall utilize CNN-based deep learning models, operating at 30 frames per second on edge computing platforms such as NVIDIA Jetson. The classification shall align with standard vehicle categories used by relevant regulatory bodies, including BRTA or RHD classification schemes.

Fallback Toll Estimation via AVC and Machine Learning

In the event that RFID, DSRC, or ANPR technologies fail due to environmental interference, signal occlusion, or data inconsistency, the system shall employ fallback toll estimation mechanisms based on AVC and machine learning. These AI-driven systems shall classify vehicles using visual characteristics, ensuring toll assignment continuity. AVC shall perform real-time classification using physical parameters, while machine learning models shall analyze video feeds and historical toll data to estimate toll charges with high accuracy.

The machine learning modules shall incorporate advanced object detection frameworks (e.g., YOLO, Faster R-CNN) and run on embedded edge devices, with classification and estimation performed in under one second. These modules shall be fully integrated with the central toll engine, generating fallback transactions that are automatically flagged for review or audit, thereby maintaining revenue protection and operational resilience in all failure scenarios.

7.37.2.3. Toll Plaza Geometric Requirements

Toll Island Design: Toll islands shall serve as raised structural platforms for supporting toll booths, vehicle classification systems, payment equipment, protective devices, and associated infrastructure. These islands shall typically be constructed of reinforced concrete and designed to withstand dynamic vehicular forces, accommodate embedded service ducts, and provide a safe working environment for toll operators.

Width: The width of the toll island shall be based on the overall footprint of the toll booth or equipment cabinet, along with the required lateral clearance between the island kerb face and the booth or equipment face. The minimum allowable width shall be 1.2 meters, while most practical configurations range between 1.8 meters and 2.1 meters. A nominal width of 2.0 meters may be adopted for outline design purposes, subject to confirmation during detailed design. The final width shall consider:

- The type of toll collection equipment (manual, semi-automatic, or ETC)
- The inclusion of stairwells or tunnel access
- Operator access and safety clearances
- Clearance requirements for Heavy Goods Vehicles (HGVs) and wide mirror profiles

A minimum clearance of 0.5 meters shall be provided between the outer edge of the toll island kerb and any nearby obstruction (e.g., signage posts, protection barriers), allowing for driver-side window operation and reducing the risk of mirror collisions.

Length: The toll island length shall be determined by the configuration of all installed equipment and protection systems, including:

- Toll classification sensors

- Electronic tolling readers (e.g., RFID, DSRC)
- ANPR cameras
- Protective barriers and nosing elements
- Toll booth structures

The total island length shall typically range between 6 meters and 40 meters, depending on system complexity and plaza layout. Final dimensions shall be verified through site-specific planning, equipment layouts, and traffic simulation modeling.

Kerb and Surface Design: Toll Island kerb heights shall be between 150 mm and 350 mm, with a reduced kerb height in the driver payment interaction zone to allow door opening if needed (e.g., in case of dropped payment). All kerb edges shall be finished with a rounded or chamfered profile to reduce impact severity. The surface of the island shall be skid-resistant and sloped appropriately to prevent water accumulation. Drainage channels may be incorporated if necessary.

Utilities and Services: Toll islands shall be equipped with electric power and water access points to support routine cleaning, lighting, equipment maintenance, and future technology upgrades. Adequate conduit space and service ducting shall be included in the foundation for cabling, sensors, and network connections.

Signage and Visibility: Any signage placed on toll islands shall conform to applicable traffic control regulations and align with advance toll signs and plaza guidance systems. The location and height of signage shall not obstruct the operator's view or the field of detection of any classification or tolling device.

Toll Lane Width: Toll lanes shall be designed with a clear width between 3.0 and 3.3 meters, measured from kerb to kerb. This range supports controlled vehicle speed while guiding vehicles toward the point of transaction, whether handled by an attendant or an automated system. Where high-clearance vehicles are expected, additional lateral space shall be considered to avoid damage to mirrors or lane-side equipment. All standard lanes shall maintain a consistent width to simplify traffic operations. A separate facility must be designated for oversized or abnormal loads, incorporating increased lane width and appropriate signage. According to IRC: SP:84-2019 – *Manual of Specifications and Standards for Four-Laning of Highways*, lanes for over-dimensioned vehicles shall be 4.5 m. In addition, a 3.5-meter-wide emergency access and service lane shall be constructed parallel to the toll lanes for emergency vehicle use and maintenance operations. This lane shall connect the entry and exit points of the plaza.

Toll Plaza Width: The total width of the toll plaza shall be based on the number of operational lanes required to handle forecasted traffic volumes during peak hours. This includes the combined widths of toll lanes, islands, and any supplementary spacing or buffer zones. Calculations shall consider both

normal operational traffic and periods of peak demand. Once the total number of lanes is determined, the full cross-sectional width of the toll plaza can be established accordingly.

Toll Plaza Length and Longitudinal Layout: The longitudinal layout of the toll plaza shall include distinct functional zones to facilitate smooth vehicle movement before, during, and after tolling. These zones are defined as follows:

- **Approach Zone:** This zone shall allow vehicles to transition from the mainline carriageway into the tolling area. It shall be at least 120 meters long, widening gradually to the full plaza width at a taper ratio of 1:20. The design speed for this section may be less than the upstream highway's free-flow speed, with a maximum plaza design speed of 85 km/h considered acceptable for modelling purposes. Taper design shall align with national geometric design standards.
- **Queue Zone:** The queue area shall accommodate vehicles awaiting toll processing. The design shall provide stacking capacity for approximately 15 vehicles per lane, equating to a zone length of about 90 meters. To confirm adequacy, traffic simulation software shall be used to model vehicle queuing during the peak annual hourly flow, ensuring that queues remain within the plaza footprint and do not spill back onto the mainline carriageway.
- **Recovery Zone:** Following toll collection, a minimum of 60 meters of straight roadway shall be provided to allow vehicles to regain appropriate travel speeds safely. This section supports the smooth transition from a stationary or slowed state to re-entry into flowing traffic.
- **Departure Zone:** The final segment of the toll plaza shall guide traffic from the plaza width back into the standard road configuration. This transition zone shall be at least 100 meters long and use a taper ratio of 1:25. It shall include appropriate lane markings and channelization to promote safe merging and controlled lane convergence.

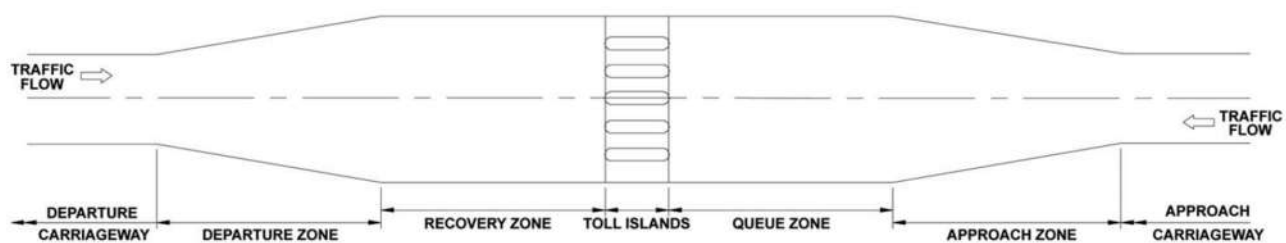


Figure 7.37-1: Toll Plaza layout and terminologies.

All zone dimensions and configurations shall be validated through microsimulation modelling tools, allowing for real-world traffic conditions to be replicated and the layout to be optimized for safety, efficiency, and throughput.

7.37.2.4. Toll Lane Throughput and Lane Requirements

Toll plaza lane requirements shall be determined based on the design vehicle flow rate and the throughput capacity of each tolling method. However, a number of factors influence the expected throughput at the toll plaza. The important factors include the category of toll collection, categorization of vehicles, presence of rising-arm barrier, heavy vehicle proportion, availability of dedicated lanes for frequent users, etc. The following throughput figures are adapted from TA 98/08:

Table 7.37-1: Typical toll Lane throughput for different toll collection categories.

Methods of Toll Collection	Car Throughput (vph)	HV Throughput (vph)
Electronic Toll Collection (ETC)	450–900	300–500
Card Payment (Credit/Debit)	200–350	150–250
Manual Collection	250–550	200–300

Note: HV = Heavy Vehicles; vph= vehicles per hour; 900 vph = 4 seconds per transaction; 450 vph = 8 seconds per transaction; 300 vph = 12 seconds per transaction; 200 vph = 18 seconds per transaction.

Peak hour traffic shall be divided by the expected throughput for each lane type, applying an 85% efficiency factor to account for lane imbalance and operational delays. Where possible, simulation software shall be employed to model plaza behavior and verify queue management during peak hours.

Design vehicle flow rate:

The design vehicle flow rate may be derived from the peak hourly traffic capacity of the upstream or downstream roadway. However, in certain cases, a lower design flow threshold may be considered where it leads to a more cost-effective design without compromising operational efficiency or service quality.

The selection of design flow parameters shall be guided by:

- The expected traffic mix (including vehicle classifications and volume distribution)
- The location-specific context of the toll plaza
- The presence and proportion of ETC express lane users, if applicable

In particular, sites located near traffic-generating facilities—such as sports complexes, commercial hubs, or event venues—shall consider the potential for intermittent but significant traffic surges. These atypical peak events shall be accounted for in the plaza configuration or managed through temporary traffic strategies.

Where ETC express lanes are incorporated, the projected share of vehicles utilizing these lanes shall be factored into the overall lane distribution and throughput capacity planning.

The design process shall include a provisioning strategy to accommodate future increases in traffic demand.

Vehicle Categorization:

The Electronic Toll Collection System (ETCS) shall be capable of automatically differentiating between various vehicle categories to support toll rate variation based on defined classification criteria. It is common for toll tariffs to differ between vehicle types such as passenger cars, commercial vehicles, utility vehicles, heavy vehicles (HVs), and others. However, the categorization system shall follow the RHD vehicle classifications, the BRTA classifications, or as determined by the Engineer.

7.37.2.5. Toll Lane Assignment

Toll plaza lane configuration shall be designed to optimize vehicle throughput, minimize driver confusion, and adapt to changing traffic patterns and payment technologies. Lane assignments shall consider traffic volumes, vehicle types, ETC penetration rates, and the potential need for lane reconfiguration during peak periods.

To ensure operational flexibility and efficiency, plaza layouts shall incorporate provisions for lane convertibility between Manual (attended), Semi-automatic (card/ticket payment), and automatic (ETCS) modes based on demand. Lane reconfiguration convertibility prioritizes operational flexibility and is particularly useful during periods of fluctuating traffic demand, such as Eid festival seasons, where ETCS/Semi-automatic system usage may be low and manual processing is required more. Rather than requiring major infrastructure changes, lane convertibility allows operators to adjust the number of lanes assigned to each payment type based on real-time demand. Again, as ETCS adoption increases, traffic throughput improves. In such scenarios, the simplification and clustering of lane types becomes essential to support higher-speed tolling operations and reduce driver confusion in lane selection.

Lane Positioning Guidelines

The following guidelines shall be adhered to:

- All toll lanes accepting the same payment types shall be grouped or clustered together, particularly during high traffic periods. This enables effective advance signage and allows drivers to make timely lane selection decisions.
- ETCS dedicated lanes shall be positioned to the right side of conventional toll plazas. Mixed-use express lanes shall, by definition, be positioned adjacent to the conventional toll plaza, be physically separated from standard toll lanes, and consist of a minimum of two continuous lanes to safely accommodate high-speed, bidirectional, or unidirectional traffic flow.

- Manual or attended lanes, typically slower due to manual processing, shall be located on the left side of the plaza to accommodate oversized or permit vehicles.
- The far-left lane shall be designed to accommodate oversized or special permit vehicles, ensuring sufficient width and clearance.
- Semi-automatic (card/ticket machines) lanes shall be located to the right of attended lanes, as they process vehicles faster and offer flexible conversion potential to ETCS lanes.

7.37.2.6. ETC Express Lane Guidelines

Express lanes for Electronic Toll Collection (ETC) are essential components of modern toll plaza design to enable uninterrupted, free-flow tolling for vehicles equipped with onboard identification technologies such as RFID or DSRC (especially on high-speed expressways). The following requirements shall apply to the design and construction of ETC express lanes on new toll plaza facilities. These specifications are adapted from international expressway tolling guidelines and reflect best practices found in recommended guidelines of FHWA (section 2.3.4). Adaptations shall be made in accordance with applicable local standards and traffic regulations.

- **Lane Continuity and Capacity:** The number of ETC express lanes shall be equal to the number of through lanes on the approach roadway. If the approach roadway is intended for future widening, the express lane configuration shall include provisions for expansion to accommodate the anticipated number of lanes.
- **Mainline Alignment and Driver Expectation:** ETC express lanes shall be aligned such that they appear as a natural extension of the mainline, without requiring a change in the driver's lane path, speed, or steering behavior. Lane positioning shall ensure intuitive and unobstructed movement through the tolling zone.
- **Separation from Conventional Toll Traffic:** ETC express lanes shall be physically and operationally separated from adjacent conventional toll lanes using appropriate barriers, medians, or channelizing devices. This separation shall be consistent with the expressway design criteria applied to both approach and departure roadway sections.
- **Vehicle Accessibility:** ETC express lanes shall be designed to allow use by all vehicle types permitted on the corresponding expressway segment. No restrictions such as "cars only" or "trucks only" shall be imposed on ETC express lanes unless such restrictions are already in effect for the general roadway facility.

- **Geometric Design Standards**

The geometric design of ETC express lanes shall conform to the same criteria used for the mainline expressway, including:

- Vertical and horizontal curvature
- Cross-slopes and pavement grades

- Vertical clearances and roadside clear zones
- Stopping sight distance

Design speeds and safety margins shall match those established for the approach and departure segments.

- **Speed Limit Consistency:** The posted speed limit for ETC express lanes shall be the same as the posted speed on the adjoining mainline expressway. No speed reductions specific to tolling operations shall be imposed in the express lane.

7.37.2.7. Toll Plaza Location Requirements

For new construction of Toll Plaza locations, the following guidelines shall be adhered to based on FHWA and AASHTO standards:

- A minimum spacing of 1.5 km in urban areas and 5 km in rural sections between toll plazas and nearby interchanges.
- Toll plazas must be visible from a distance that allows drivers to perceive, react, and stop if necessary while traveling at posted speeds.
- Plazas should be located on straight (tangent) road segments to avoid sharp curves, which could reduce sight distance or increase collision risk.
- Toll Plaza location should avoid merging/diverging ramps, trumpet interchanges, or overlapping movements within the approach and departure zones.
- Free from risk of flooding and submergence

7.37.2.8. Pavement

Pavement in toll zones shall be designed for high durability and resistance to concentrated loading from slow-moving and stopping vehicles, repetitive loading from frequent braking and acceleration, high-axle-load traffic, and lane-changing actions.

Skid Resistance

Pavement surfaces within toll plaza zones are subject to progressive deterioration, typically beginning with a decline in skid resistance at the surface layer. Skid resistance performance is largely influenced by two surface characteristics: macrotexture and microtexture. Macrotexture refers to the broader, coarse-scale irregularities on the pavement surface, which are shaped by the size, angularity, and distribution of the coarse aggregates, as well as by the construction methods used during surface placement. In contrast, microtexture encompasses the finer surface irregularities at the aggregate level and plays a critical role in maintaining friction, particularly in wet conditions. Microtexture durability

is dependent on the inherent surface roughness of the aggregates and their resistance to polishing due to repeated vehicle loading and environmental exposure. To ensure adequate skid resistance at toll plaza approaches, the pavement shall be designed and maintained with specific attention to both of these texture characteristics.

- Skid Resistance Value (SRV) is used in testing finished surfaces (like concrete or asphalt) for site-specific safety performance.
- Polished Stone Value (PSV) is used for assessing the aggregate used in surfacing materials—ensuring that it won't polish too much under traffic.

Skid Resistance Value (SRV)

Skid Resistance Value (SRV), measured using a pendulum test in accordance with BS EN 13036-4 or TRRL Road Note 27, indicates a surface's slip resistance, with higher SRV indicating better slip resistance.

Skid Resistance Values (SRVs) and calculated corresponding CoFs for different road conditions. The two measures of friction are related by the Equation: $\text{CoF} = (3 \times \text{SRV}) / (330 - \text{SRV})$. The minimum recommended values of skid resistance and calculated corresponding CoFs for different sites on road networks under typical wet conditions are shown in Table.

Table 7.37-2: Minimum recommended Skid Resistance Values for different road network sites, under wet conditions and measured using the British Pendulum Tester.

Type of Site	Minimum Recommended Skid Resistance Value (SRV)	Corresponding Coefficient of Friction (CoF)
Roundabouts	65.0	0.74
Bends with radius <150 m on unrestricted roads		
Gradients 1 in 20 or steeper, >100 m length		
Approaches to traffic lights on unrestricted roads		
Motorways and heavily trafficked roads in urban areas (>2000 vehicles/day)	55.0	0.6
All other sites	45.0	0.47

Skid resistance values for Tolla Plaza approaches shall not fall below 65 SRV to ensure vehicular control in wet conditions.

Figure 7.37-1 shows the variation of the coefficient of friction during a rain event and corresponding Skid Resistance Values (Blake et al., 2017).

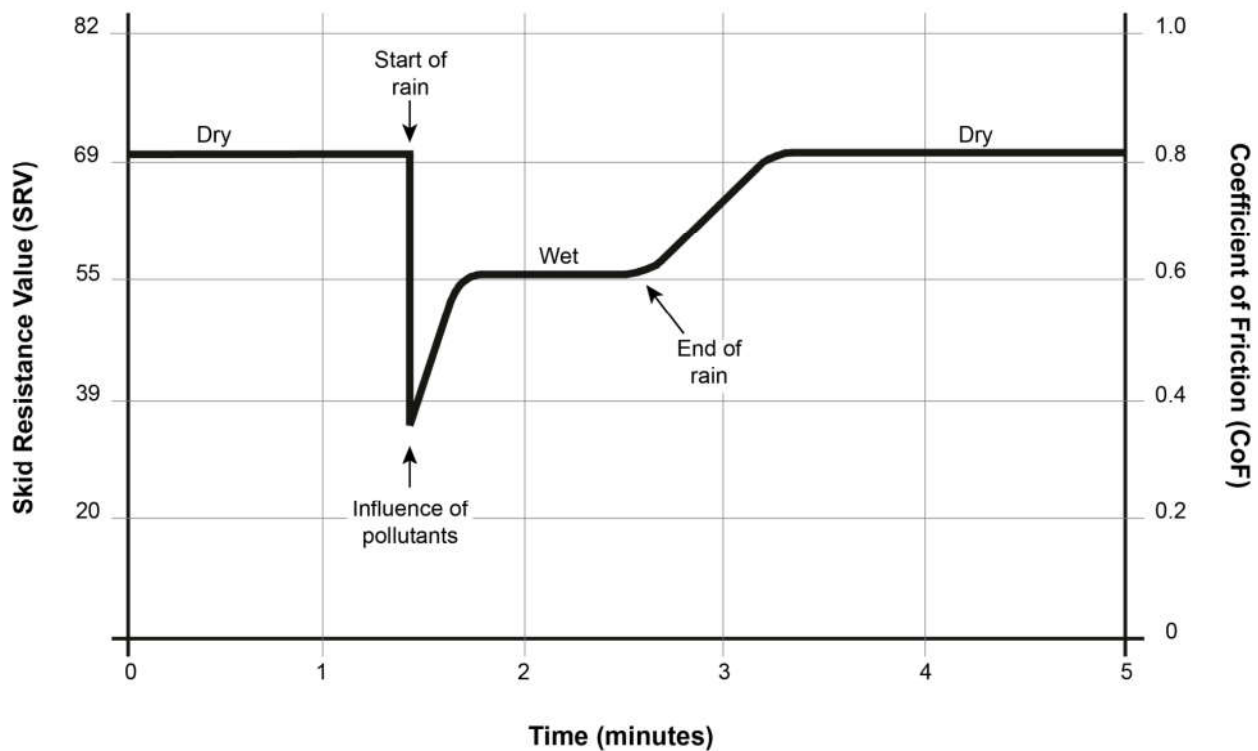


Figure 7.37-2: Coefficient of friction (CoF) and Skid Resistance Value during an event of rain (Blake et al., 2017).

Polished Stone Value (PSV)

Polished Stone Value (PSV) reflects the resistance of aggregates to polishing by traffic, with higher values indicating better ability to retain microtexture and thus maintain skid resistance over time. As per CD 236 (DMRB 7.5.1), the PSV requirement is directly tied to traffic category and the type of site.

toll plaza areas shall be considered as high-risk zones, specially at the following segments:

- Entry/exit lanes
- Toll collection zones
- Queue and departure lanes

For high-risk zones (e.g., sharp turns, pedestrian access near booths), a minimum PSV value of 65 is specified. However, with a higher amount of cumulative vehicles/lane/day, PSV 68+ is often preferred, and the recommendation is to use High Friction Surfacing (HFS) for 3000+ cumulative vehicles/lane/day.

Where a material is labeled as “68+” in standards, it must comply with the requirement that none of the last three PSV tests fall below 68.

Limestone aggregates shall not be used where PSV specifications are applied, unless performance data justifies it under similar traffic and environmental conditions.

Aggregates must also comply with the maximum Aggregate Abrasion Value (AAV) limits to ensure resistance to wear. For toll plaza applications, the AAV shall not exceed the values recommended in Table 7.37-3 (adapted from Table 3.10 of CD 236).

Table 7.37-3: Maximum AAV of chippings, or coarse aggregates in unchipped surfaces, for new surface courses, excluding pavement quality concrete.

Traffic (cv/lane/day) at design life	≤ 250	251 - 1000	1001 - 1750	1751 - 2500	2501 - 3250	> 3250
Max. AAV for chippings for Hot Rolled Asphalt, surface dressing, slurry/micro-surfacing system	14	12	12	10	10	10
Max. AAV for aggregate in a thin surface course system, exposed aggregate concrete surfacing	16	16	14	14	12	12

High Friction Surfacing (HFS): High Friction Surfacing (HFS) shall be provided at toll plaza areas where enhanced skid resistance is required due to frequent braking, stopping, or turning maneuvers, particularly under wet or contaminated surface conditions.

Material Requirements

- Aggregate shall be calcined bauxite or other approved material with a minimum Polished Stone Value (PSV) of 70. Conformity to BS EN 13043 is required.
- Binder shall be a cold-applied thermosetting resin, such as epoxy, polyurethane, or methyl methacrylate. Binder must comply with BS EN 13813 and be resistant to UV, oil, fuel, and temperature variation.

Application Requirements

- Surface preparation shall ensure a clean, dry, and dust-free substrate.
- Application shall follow manufacturer’s specifications for binder-to-aggregate ratio, spread rate, and curing time.
- Minimum coating thickness: as per product datasheet, typically 3–5 mm.
- Application shall not proceed in ambient temperatures below 5°C or during precipitation.

- The finished surface shall achieve a Skid Resistance Value (SRV) ≥ 65 , tested using the British Pendulum Tester in accordance with BS EN 13036-4.
- The surfacing shall exhibit no delamination or aggregate loss under normal traffic loading for a minimum of 5 years.

Pavement Types

The toll plaza pavement shall be designed to ensure long-term performance under conditions of slow-moving, high-axle-load vehicles, frequent braking and acceleration, and potential contamination from oil and fuel. The pavement must also facilitate embedded systems like sensors or inductive loops. The following criteria shall be met:

Toll Lanes and Island Areas

- The toll lane surface shall consist of Pavement Quality Concrete (PQC) with a minimum thickness of 300 mm, constructed using M40 grade concrete or higher, in line with IRC:58 and MoRTH Section 1500 or as directed by the Engineer.
- Design of PQC shall conform to the expected axle load spectrum for the design life.
- The concrete shall be jointed reinforced concrete pavement (JRCP) or continuously reinforced (CRCP), depending on site conditions.
- A steel-troweled finish with a textured surface (e.g., broom finish or exposed aggregate) shall be provided to improve skid resistance.
- Where automated systems are present (e.g., RFID, AVC, ANPR sensors), the surface must be level and vibration-resistant to avoid calibration drift.

Adjacent Approach and Departure Lanes

- The approach and departure zones outside the rigid pavement shall be flexible or composite pavement.
- The bituminous surface course shall use Polymer Modified Bitumen (PMB) to enhance rutting resistance, fatigue life, and oxidation resistance.
- Surface, binder, sub-base, and base layers shall be designed based on the cumulative standard axles and traffic loading conditions.

Run-On Concrete Slabs

To ensure a smooth structural transition between the rigid pavement of the toll island and the adjacent flexible pavement lanes, reinforced concrete run-on and run-off slabs shall be provided on both entry and exit sides of the toll island.

Design and Construction Requirements

- These slabs shall act as a buffer zone to absorb differential movement and reduce the risk of Joint failure, edge cracking, and settlement at the interface
- Thickness: Same as main toll slab (typically 300 mm)
- Dowel bars and tie bars shall be considered as required for load transfer and crack control
- The slab shall rest over a well-compacted granular sub-base with a separation membrane (e.g., polythene or geotextile) to prevent reflective cracking.
- Run-on slabs shall be cast monolithically or integrally with the toll slab where possible to avoid vertical displacement.
- Expansion joints may be provided at the far end of the slab to absorb thermal movement and vehicular stress.
- The design criteria may consider IRC:58 and MoRTH Section 1500 or as directed by the Engineer.

7.37.2.9. Drainage

The surface of the toll plaza, including approach and departure zones, shall be designed to prevent standing water or water accumulation. The drainage system for toll plazas shall comply with the guidance set out in DMRB Volume 4 and the following provisions:

- A minimum crossfall of 2.5% shall be maintained across the pavement to promote transverse drainage.
- A minimum longitudinal gradient of 0.5% is recommended to facilitate flow toward the drainage channels.
- Where possible, drainage flow paths should be aligned with the longitudinal gradient of the carriageway.
- For wide carriageways where longitudinal gradient is low or zero, proper crossfall must be provided along with continuous edge drains to ensure adequate surface runoff.
- The transition zones between mainline carriageways and the toll plaza area shall incorporate heavy-duty, high-performance linear drainage systems. These may include longitudinal linear channel drains combined with transverse drains to manage surface runoff across the entire toll area.
- If a longitudinal drainage system is adopted, it shall be aligned with the theoretical or actual lane dividers, making it visually consistent with lane markings for driver clarity.
- The potential safety implications of linear drainage systems on powered two-wheel vehicles (e.g., motorcycles) shall be addressed, ensuring that the drainage elements do not pose slip or handling hazards.
- Grates over longitudinal drains shall be non-slip and rated for minimum 400 kN load-bearing capacity.

- The drainage design must consider ease of access for maintenance activities. Layout should minimize disruption during maintenance, ensuring that temporary closures do not significantly affect off-peak capacity or overall plaza performance.

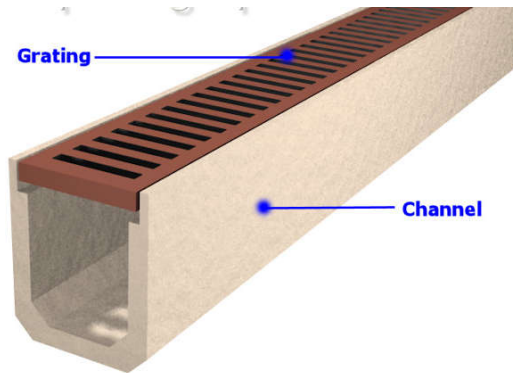


Figure 7.37-3: Use of grates over longitudinal drain system.

7.37.2.10. Lighting

Lighting shall be designed to provide uniform and reliable illumination across all operational areas of the toll plaza, including queue lanes, booths, canopy zones, and transitions to mainline roadways. The following provisions shall apply:

- LED luminaires in the toll lanes shall be installed to provide a minimum average illuminance of 20 lux, consistent with industry guidelines (see details in the following description)).
- Lighting poles shall be installed at heights between 6 and 8 meters to balance coverage and glare control.
- Luminaires shall include glare-reduction optics or cutoff shields to ensure driver comfort and visual clarity.
- A UPS system shall support lighting for a minimum of 30 minutes in the event of a power outage.
- A diesel generator shall be provided to ensure at least 8 hours of continuous lighting operation.
- Lighting shall be located to avoid shadowing toll booths, queue areas, and canopy overhangs.
- Lighting layout shall be designed following IESNA RP-8, BS 5489, and in alignment with DMRB Volume 8 guidance on visibility and driver safety.

According to BS EN 13201-2:2015 - *Road Lighting - Part 2: Performance Requirements*, the "**M**" lighting classes (M1–M6) are intended for **motorized traffic routes**, particularly roads allowing medium to high driving speeds. The classes represent different performance levels, where **M1** has the

highest lighting standard (for motorways and heavy traffic), and **M6** the lowest (for low-speed or less critical roads).

Table 7.37-4: Lighting Requirements on motorways (per BS EN 13201-2:2015).

Lighting Class	Min. Avg. Luminance (L) (cd/m ²)	Overall Uniformity (U _o)	Longitudinal Uniformity (U _l)	Uniformity in Wet Conditions (U _{ow})
M1	2.00	0.40	0.70	0.15
M2	1.50	0.40	0.70	0.15
M3	1.00	0.40	0.60	0.15
M4	0.75	0.40	0.60	0.15
M5	0.50	0.35	0.40	0.15
M6	0.30	0.35	0.40	0.15

Note: cd/m² = candela per square meter (luminance); **Lux (lx)** = illuminance (light falling on surface); **U_o (Overall Uniformity)**: Ratio of minimum to average luminance; higher values mean more consistent lighting; **U_l (Longitudinal Uniformity)**: Measures brightness consistency along the driving direction; **U_{ow} (Wet Road Uniformity)**: Ensures safety during wet conditions.

BS EN 13201-2:2015 is mainly intended for open road sections, with M1–M6 classes used for general carriageways. However, toll plazas have unique requirements:

- Mixed traffic (frequent stopping, merging, diverging)
- Presence of structures (canopies, booths)
- Need for high visual clarity at low speeds

Thus, for a toll plaza the following lighting classes shall be matched depending on traffic volume, design speed, and layout:

Table 7.37-5: Lighting Requirements at Toll Plaza.

Zone	Suggested Class	Target Luminance (cd/m ²)	Lux Approx. Equivalent
Mainline/through lanes	M2	1.5	~30–35 lux
Queue lanes & toll zones	M3–M4	0.75–1.0	~20–30 lux
Parking/maintenance areas	M5–M6	0.3–0.5	~10–15 lux

Note: cd/m² = candela per square meter (luminance)

Thus, lighting for approach, queue, recovery, and departure zones shall conform to lighting class M3 or M4, per BS EN 13201-2:2015, providing:

- Average luminance ≥ 0.75 cd/m² (equivalent to 20–25 lux on light-toned pavement)
- Overall uniformity (U_o) ≥ 0.40
- longitudinal uniformity (U_l) ≥ 0.60

- Wet road uniformity (U_{ow}) ≥ 0.15

LED luminaires (6,000-10,000 lm) shall be mounted at heights between 6–8 meters, with an opposite or staggered arrangement depending on lane configuration. Pole spacing shall not exceed $3.5 \times$ mounting height (e.g., 20 m spacing for 7 m height) to maintain ≥ 20 lux average illuminance and uniformity $U_o \geq 0.35$.

It shall be confirmed using lighting simulation tools like DIALux or AGi32, whether the above /proposed setup achieves >20 lux average with acceptable uniformity ratio ($U_o \geq 0.35$) and low glare, which is suitable for M3/M4.

7.37.3. Safety Requirements

7.37.3.1. Traffic Signals

Traffic signals shall be installed in each toll lane to control vehicle movement. For semi-automatic ECTS/card/ticket payment or similar, these signals will instruct drivers to stop for toll payment and to proceed once the transaction has been successfully completed. Only type-approved signal heads displaying red and green aspects shall be used for this purpose.

In lanes where rising-arm barriers are used in addition to traffic signals, the operation of both systems must be integrated to prevent conflicting instructions to drivers. Although linked, each system must also be capable of operating independently, but only when the other system is non-operational or undergoing maintenance.

The placement and height of traffic signals should be determined in coordination with other toll plaza equipment and the types of vehicles expected in the lane. This ensures maximum visibility and effective operation. If any proposed configuration deviates from standard regulations, necessary approvals must be obtained prior to installation.

To enhance visibility during adverse weather or low-light conditions, hazard warning beacons should be placed at the upstream end of toll islands. These beacons must be designed with consideration for their frequency, intensity, and light characteristics to avoid causing discomfort or confusion to drivers, especially during times of low traffic.



Figure 7.37-4: Use of traffic signal in front of toll booth.

7.37.3.2. Traffic Signage

Toll plazas and their approach roads require a higher density of traffic signs than typical road sections. This is especially important where lanes are designated for specific vehicle types (e.g., motorcycles, heavy vehicles, or emergency vehicles). Signs must provide clear guidance, instructions, and regulatory information to drivers approaching and using the toll facility.

Each toll lane must be equipped with variable message signs (VMS) to display real-time lane status and accepted payment methods. These signs must be visible from a safe distance and clearly indicate which lanes are operational and the permitted payment options. Non-standard VMS designs must be authorized as per regulatory procedures.

Advance signs should be installed on main and alternative approach routes to inform drivers about:

- Toll payment requirements
- Vehicle classifications
- Toll rates for different time periods (if any)
- Accepted payment methods
- Availability of alternate, toll-free routes

Advanced signage should allow sufficient time and distance for drivers to make informed decisions and safely select the correct lane, minimizing abrupt lane changes.

Signs should use a consistent combination of symbols, colors, and legends to enhance readability and driver understanding. Overhead and roadside signs must be positioned to maintain visibility and avoid driver confusion.

To ensure safety in the Departure Zone, at least 200 meters from the end of the toll departure zone shall be considered as a no-signage zone for high-speed corridors (≥ 80 km/h), unless otherwise approved by the Engineer. For lower speed corridors, the distances may vary and be lowered as approved by the Engineer. According to the FHWA's "State of the Practice and Traffic Control Strategies at Toll Plazas", the departure recovery zone should be at least 60 meters and preferably 90 meters to allow sufficient driver reorientation, acceleration, and initial merge distance after exiting the plaza

For detailed guidance on traffic sign usage, design, and maintenance practices for Toll Plaza, refer to the RHD Road Safety Engineering Manual 2024.

7.37.3.3. Pavement Marking

Lane lines shall be applied within the toll plaza approach and departure zones to optimize the use of available carriageway width and guide vehicles safely into the correct toll lane. These markings play a key role in maintaining vehicle alignment and lateral positioning, thereby improving operational safety and traffic flow efficiency.

Chevron road markings must be implemented both before and after toll booth islands to assist in the divergence and convergence of vehicle paths. These markings support the safe separation of vehicles as they enter the toll lanes and promote smoother merging upon exit.

Where appropriate, "Keep Clear" road markings shall be installed ahead of toll booths to discourage queue blocking and ensure vehicles only proceed when the path is clear.

Markings should be designed to discourage last-minute lane changes in the toll plaza approach zone, which are a common cause of minor collisions and erratic driving behavior. In cases of lane malfunction or temporary closure, traffic cones or delineators may be deployed to maintain orderly lane usage and manage vehicle movements safely.

Additional visual or physical measures, such as special pavement textures, colored pavement, raised studs, or reflective markings, may be applied near and within the toll area to increase driver attention and promote compliant behavior.

All road markings, studs, and temporary devices must be:

- Maintained in good condition for visibility under all lighting and weather conditions.
- Compliant with standards and guidance specified in the RHD Road Safety Engineering Manual 2024.

For detailed guidance on pavement marking usage, design, and maintenance practices for Toll Plaza, refer to the RHD Road Safety Engineering Manual 2024.

7.37.3.4. Speed Control

Speed reduction for all vehicles approaching a conventional toll plaza, particularly after diverging from mainline through lanes/ express lanes, remains a key safety concern, especially with the increasing integration of ETCS (Electronic Toll Collection Systems) and dedicated lanes. Vehicles entering and exiting these lanes at higher speeds can create significant speed differentials with adjacent vehicles that must stop to pay tolls or collect tickets. Hence, the road geometry and signage should be designed to promote gradual deceleration as vehicles transition from high-speed road segments to the toll area. While vehicle movement is generally more controlled on the departure side, differences in acceleration capabilities, specially between light vehicles and heavy trucks, make it challenging for traffic to merge smoothly as toll lanes reduce into fewer mainline lanes. To ensure safe merging, vehicles should be able to accelerate to match the prevailing mainline speed, which may be hindered when trailing slower-moving vehicles.

According to the FHWA's "State of the Practice and Traffic Control Strategies at Toll Plazas", the following shall be maintained for the approach and departure zones of a Toll Plaza:

Approach Zone Speed Reduction Measures

The use of speed bumps, raised pavement materials, or other harsh in-pavement devices **shall not be permitted** in the approach zone, as they may cause passenger discomfort and potential vehicle damage. Rumble strips (slotted or raised thermoplastic) may be used.

The following speed reduction strategies shall be implemented as appropriate to the site conditions:

- Advance speed limit signs shall be placed at suitable intervals in advance of the toll plaza.
- Speed warning signs shall be used to inform drivers of reduced speed requirements approaching the plaza.
- Chevron markings or other directional pavement markings shall be applied to visually reinforce speed control and lane alignment.
- Channelization devices, such as flexible posts or bollards, shall be used to guide vehicle flow and support speed reduction.

- Reflective raised pavement markers shall be used strategically to improve lane discipline and visibility during night or low-light conditions.

Speed enforcement by highway police or designated authorities shall be used near ETC lanes, supported by adequate shoulder width or a designated pull-off area for safe monitoring.

Departure Zone Merging and Acceleration Control

- The merging area downstream of the toll plaza shall be designed to accommodate differences in acceleration capabilities, particularly for heavy vehicles such as trucks, buses, and large vehicles.
- Manual toll lanes are typically positioned on the left side of the plaza; traffic management measures shall be implemented to minimize merging conflicts and speed differentials.
- Regulatory signage shall be installed immediately downstream of the toll booths to instruct trucks, buses, and other slow-accelerating vehicles to remain in the left-most lane after exiting the toll lanes.
- This lane discipline shall be enforced to allow faster-moving vehicles, particularly from ETC or express lanes, to safely overtake from the right, thereby improving flow efficiency and reducing the risk of lane-change conflicts.

Speed Limit

The maximum speed limit on the approach to a toll plaza shall be determined based on the design speed of the mainline road, expected traffic volume, and toll system type (manual, mixed-mode, or ETC). A formal risk assessment shall be conducted to determine the maximum speed limit in the Approach Zone compared to the mainline approach road, particularly under high-volume or mixed-mode tolling conditions.

According to the FHWA's "State of the Practice and Traffic Control Strategies at Toll Plazas", the maximum approach speed to toll plaza lanes shall be limited to 40–48 km/h (25–30 mph) for ETC dedicated lanes, and lower where site geometry or traffic conditions present safety risks. Where manual or cash lanes exist, approach speeds should be reduced accordingly, supported by signage and enforcement as appropriate. The objective is to ensure safe deceleration, minimize lane-changing conflicts, and allow drivers to make appropriate toll lane selections. Table 7.37-6 shows the recommended speed limits for Toll Plaza Approach for different levels of mainline/through lane design speed limits.

Table 7.37-6: Recommended Speed for Toll Plaza Approach

Mainline Design Speed (km/h)	Buffer Zone Speed (km/h)	Toll Plaza Entry Speed (km/h)
100 – 120	70 – 80	30 – 40
80 – 100	50 – 60	30 – 40
60 – 80	40 – 50	25 – 30
<60	Not always required	25 – 30

A buffer or transition zone of 200–300 meters should be provided to allow gradual deceleration before entering the toll plaza. Advance speed limit signs shall be installed at appropriate intervals (e.g., 300m, 150m, 75m).

7.37.3.5. Protection Devices

All toll islands shall be equipped with appropriate protective safety devices to shield toll booths, canopy structures, toll attendants, and toll lane equipment from vehicle impacts. Protection devices shall be designed to:

- Effectively deflect or absorb the impact of an errant vehicle.
- Prevent direct collision with structural elements or personnel.
- Minimize injury risk to vehicle occupants during any impact event.

Impact Protection

Crash attenuators or protective barriers shall be installed at the upstream end of each toll island to reduce the severity of vehicle impacts.

These devices shall incorporate retro-reflective end panels, and their design and usage shall be approved by the Engineer.

Where high-risk locations exist, impact-absorbing barriers shall be installed in front of any major concrete or steel bollards located on the approach to a toll island, unless a site-specific risk assessment justifies their exclusion.

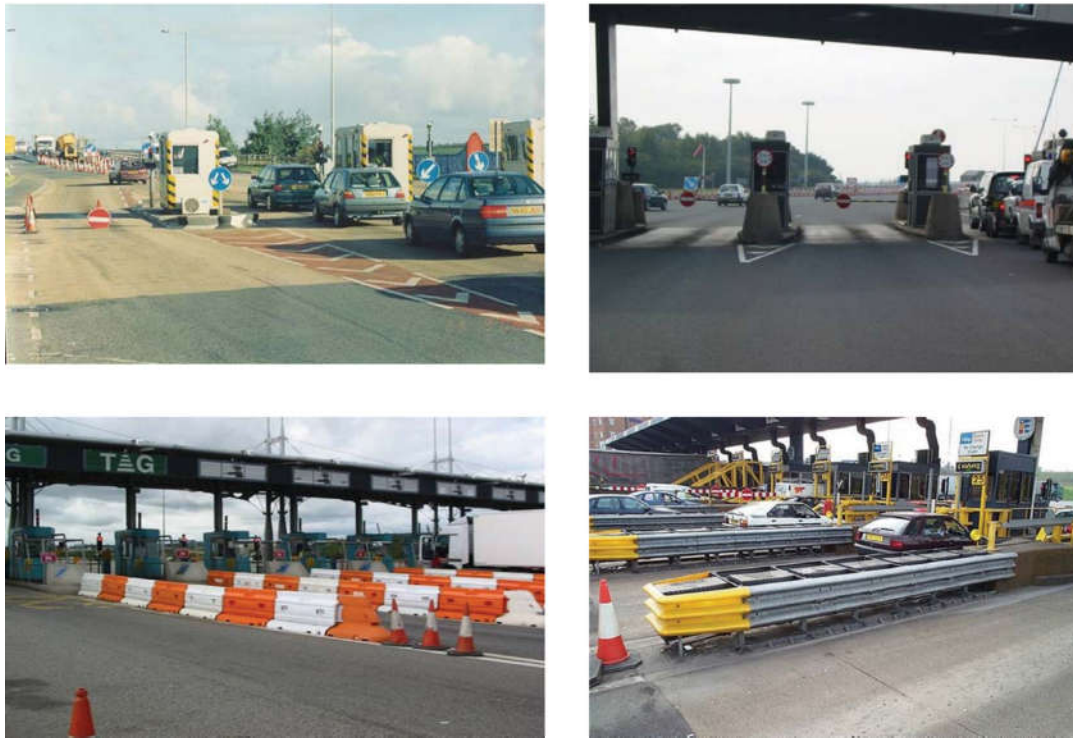


Figure 7.37-5: Example of protective systems at Toll Plaza.

Toll Attendant Safety

Protection of toll attendants shall be ensured by aligning and channeling vehicles accurately through the toll lanes using high kerbs and lateral barriers along the toll islands to maintain proper vehicle positioning. A substantial concrete or steel bollard shall be installed at the approach end of each toll island, designed to stop or deflect any errant vehicle along the lane and away from the booth. Where required, additional protective measures shall be incorporated around these bollards to enhance impact absorption and improve overall safety for toll personnel.

Further protective measures shall be installed on the approach to the toll booth to safeguard it from any vehicle loads or objects protruding from the sides, which may pose a risk of impact. These measures shall also be used to protect vulnerable components of the toll lane equipment, ensuring the continued functionality and safety of the tolling infrastructure.

A safe and clearly defined access route shall be provided for toll collection staff to move to and from the toll booths. The design shall preferably include a designated at-grade walkway located on the traffic exit side of the booths and may incorporate pedestrian signals linked to the barrier position of the respective lane to ensure safe crossing. Where feasible, tunnel access shall be considered to minimize the need for staff to cross active traffic lanes.

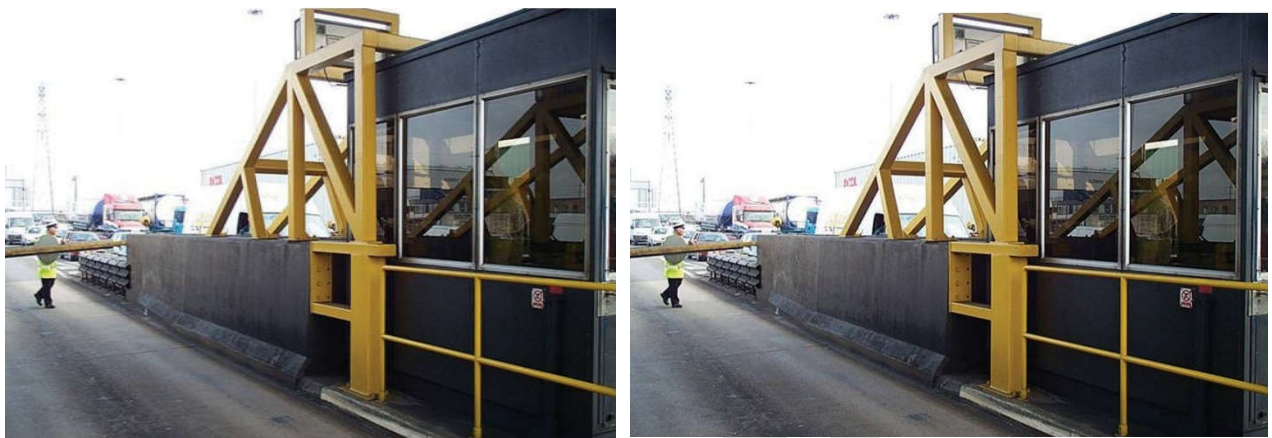


Figure 7.37-6: Examples of attendant safety systems at Toll Plaza

Vehicle Occupant Protection

Devices used to protect toll attendants can be a hazard to the occupants of any vehicle that is involved in a head-on collision. All protection devices shall be engineered to reduce the severity of injury to vehicle occupants in the event of an impact. The design of bollards and barriers shall avoid sharp edges or unshielded rigid elements in vehicle travel paths.

Adequate signage and pavement markings shall be installed in advance of the toll plaza to clearly guide drivers into the appropriate toll lanes and reduce last-minute lane changes.

7.37.4. Physical Infrastructure

7.37.4.1. Toll Island

Toll islands shall be constructed as raised platforms, typically using reinforced concrete, and shall house toll booths or collection equipment positioned for easy access by drivers. All signage on the island shall align with the overall toll plaza and advance toll information signage to ensure consistency and driver clarity.

The size of each toll island shall be based on the toll lane equipment layout, booth size, presence of tunnel access, expected HV traffic, and overall plaza configuration. Island lengths shall typically range from 6 to 40 meters, depending on safety device placement and pre-classification equipment, while the width shall ensure adequate lateral clearance between the kerb and the toll booth face (Highways Agency, 2008).

As per design criteria stipulated in IRC: SP:84-2019, traffic islands for hybrid-ETCS shall be of a minimum 25 m length and 1.9 m width. For such a toll lane to be installed with a weigh-in-motion system, the minimum length of islands shall be 35 m, where 22.5 m is on the approach side.

A minimum clearance of 0.5 meters shall be maintained between the island kerb and the nearest obstruction to avoid mirror damage and allow for slight booth projections. Kerb heights shall range from 150 mm to 350 mm, but shall be reduced in the payment area to allow door opening if needed (Highways Agency, 2008).

Toll islands shall be provided with water and electrical connections to support maintenance, cleaning, and equipment operation.

7.37.4.2. Toll Booth

Toll booths shall be designed to provide a safe, efficient, and ergonomically sound working environment for staff. The internal layout shall follow established ergonomic principles to reduce fatigue and support operational efficiency. A health and safety assessment of the booth design shall be conducted to ensure compliance with applicable workplace safety regulations and standards.

Toll booths shall be equipped to handle vehicle fire incidents and shall include appropriate fire safety equipment.

Key design considerations shall include booth size, structural materials, secure and safe access, internal and external lighting, heating/cooling (with emphasis on floor-level comfort), ventilation, and air quality monitoring systems. Additional requirements shall address staff welfare, security, effective signage, uninterrupted power supply, and provisions for other essential amenities. Environmental impacts shall also be considered in the booth design.

7.37.4.3. Canopy

All the toll lanes and toll booths shall be covered with a canopy. The canopy shall be wide enough to provide weather protection to toll operators, drivers, and facilities. The canopy shall be of an aesthetically pleasing design with cylindrical support columns located at the traffic island so that there is no restriction on visibility and traffic movement.

The specifications and design considerations for toll plaza canopies, as found in FHWA (2008), “*Best Practices for Toll Plazas*”, are primarily integrated with the lighting and drainage systems of the plaza. The canopy structure plays a critical role in:

1. **Lighting Support:** Canopy-mounted luminaires are the most common form of toll lane lighting, preferred for their ability to provide uniform illumination. Lighting intensity under the canopy

shall be a minimum of **215 lux** over a distance of **7.6 meters** on either side of the tollbooth or payment machine centerline. This lighting level supports clear visibility for both drivers and toll attendants and enhances the effectiveness of CCTV systems.

2. **Glare Reduction and Uniformity:** The lighting design should minimize glare, reduce light spillover into adjacent areas, and maintain uniformity across the toll lane. Designers are encouraged to use concealed conduit runs and island-mounted luminaires that reflect light off the canopy underside or downward-facing overhead lights.
3. **Stormwater Management:** The canopy must be integrated into the toll plaza's drainage system, ensuring that stormwater runoff is directed away from the toll lanes. This eliminates the need for trench or slot drains at the toll lane entrance, which may clog and create hazards like ice formation.
4. **Support for Safety Equipment:** The canopy should accommodate mounting points for security cameras and electronic signage, such as lane-use signals or variable message signs (VMS), which indicate lane status and accepted payment methods.

7.37.4.4. Toll Plaza Complex

A dedicated toll plaza office building shall be constructed within the toll complex to serve as the administrative and operational hub. The building shall provide comfortable, functional spaces for toll management and staff and shall include the following minimum facilities:

- Separate rooms for the toll plaza manager, cashier, support staff, and a dedicated TV monitoring/control room.
- A meeting room, customer service area, and public interaction counters for services such as the sale of smart cards, passes, or on-board units (OBUs).
- Designated restrooms and staff welfare areas.
- A strong room for secure cash handling and storage.
- A garage to accommodate a security van used during revenue transfer operations.
- Parking space on the same campus for staff vehicles and other operational vehicles.

The toll office building shall be located downstream from the toll collection point on the side where the administration building is planned (typically the left side). Its location shall account for future expansion, ensuring sufficient space is reserved for additional facilities and infrastructure upgrades.

To ensure safe and efficient movement between the toll office and each toll booth:

- An underground tunnel crossing beneath all toll lanes shall be provided, with a minimum internal width of 3.0 meters and a clear height of 2.5 meters.

- The tunnel shall be designed to accommodate both the required wiring/cable systems and convenient personnel movement.
- Adequate lighting and ventilation shall be installed throughout the tunnel.
- Alternatively, a secure overhead walkway system may be implemented if an underground tunnel is not feasible.

The toll plaza complex shall be equipped with appropriate fire detection and protection systems including:

- Smoke detectors.
- Automatic visual and audible alarm systems.
- Fire extinguishers and other fire-fighting equipment. These systems shall be installed throughout the toll office building and operational areas to safeguard personnel and road users from fire hazards.

A comprehensive security surveillance system shall be installed throughout the toll plaza complex. This system shall include:

- High-resolution CCTV cameras covering all critical areas, including toll booths, the office building, entry and exit points, and surrounding parking and support facilities.
- Remote monitoring capabilities to allow for continuous surveillance by security personnel.
- Integration with access control systems for both the toll office and tunnel/overhead walkway to ensure restricted areas are protected.
- Adequate data storage and backup systems to record and archive surveillance footage for a minimum period as required by local regulations.

7.37.4.5. Installation of Supporting Structures and Appurtenances

For toll plaza projects requiring supporting infrastructure such as gantries, foundations, power and communication systems, installation practices, grounding, lightning protection, and cable works, the general specifications developed for Axle Load Control Stations (ALCS) outlined in Sections 7.38.3.2 through 7.38.3.8 of this Specification, shall be applicable to Toll Plazas where relevant and technically appropriate.

The Contractor shall follow the technical requirements, standards, materials, workmanship, installation methods, testing procedures, and safety provisions specified in the referenced sections, except where those provisions are explicitly specific to Axle Load Control Stations, such as equipment configuration, HS-WIM/MS-WIM/LS-WIM systems. The relevant guidelines and specifications for connection to

the Main Control Centre at RHD Headquarters shall be the same, where connection shall be established from local toll plaza servers.

For Toll Plazas, integrated with ALCS-specific components shall be integrated from section 7.38.

In case of ambiguity or overlap, the Engineer shall provide clarification on the applicability of any referenced requirement to the Toll Plaza scope.

7.37.5. Hardware Components

7.37.5.1. RFID Reader

Ultra-high Frequency (UHF) Radio Frequency Identification (RFID) readers shall be used for vehicle tag authentication and number identification. It shall enable automatic toll transactions based on vehicle tag validity. The reader must be fully **compatible with the RHD toll management system**.

Technical Specifications:

Description	Value / Range
Read Range	Up to 30 meters
Operating Frequency	902–928 MHz
Supported Protocols	ISO 18000-6B, ISO 18000-6C (EPC Class 1 Gen 2)
Transmission Mode	FHSS (Frequency Hopping Spread Spectrum), Fixed Frequency
RF Output Power	Up to 32 dBm (adjustable)
Antenna Type	12 dBi (integrated or external)
Reading Modes	Auto-running, interactive, trigger-activated
Dimensions	260 × 260 × 65 mm
Weight	2.3 kg
Protection Rating	IP68 (dust-tight and water-resistant)
Operating Temperature	-20°C to +60°C
Storage Temperature	-40°C to +85°C
Power Supply	12–24 VDC
Power Consumption	Max 12W
Output Power	Up to 4W (e.r.p)
Interfaces	RS232, RS485, Wiegand, Ethernet, USB
Certifications	CE, FCC
Air Interface & Adaptive Noise Features	Shall feature an adaptive air interface capable of optimizing tag reading performance under varying interference conditions.
Application capability	Shall consistently maintain a read accuracy of over 99.5% within the specified range and include built-in diagnostic and reporting tools.

Upgradeability	The system firmware shall be upgradeable to support future protocol enhancements.
Transaction Capability	It should reliably read at least two tags per second for vehicles traveling at speeds up to 40 km/h.
Driver Software	Driver software shall be provided to enable seamless integration. This software must follow the required communication protocol and support tag filtering using EPC or Tag-TID codes with bitmask logic.

e.r.p= effective radiated power = transmitter power + antenna gain; **IP68: Ingress Protection Rating 68**; **VDC= Volts Direct Current** (Specifies the power input as direct current; common for low-voltage electronic devices); **RS232 / RS485** = Serial communication protocols used for data exchange between devices; **CE= Conformité Européenne** (Indicates conformity with health, safety, and environmental protection standards for products sold within the European Economic Area (EEA)); **FCC= Federal Communications Commission** (U.S. agency that certifies electromagnetic compatibility and radio frequency usage); **EPC= Electronic Product Code** (A universal identifier used in RFID for identifying objects); **FHSS = Frequency Hopping Spread Spectrum** (A method of transmitting radio signals by rapidly switching frequencies for better interference resistance); **SIO = Standard Interface Option** (Refers to a standardized communication protocol or method for RFID devices (related to ISO standards)).

7.37.5.2. DSRC Reader (Roadside Unit – RSU)

The DSRC Reader, also known as the Roadside Unit (RSU), is a critical component of On-Board Unit (OBU)-based Electronic Toll Collection (ETC) systems. Installed on gantries or roadside poles, it shall enable secure, real-time, bidirectional communication with OBUs using Dedicated Short-Range Communication (DSRC) technology, typically at 5.8 GHz. The RSU authenticates vehicle credentials, performs secure transaction exchanges, and transmits toll data to the central system.

Technical Specifications:

Description	Value / Range
Communication Technology	DSRC (CEN DSRC or ISO 14906 standard)
Operating Frequency	5.8 GHz (5.795 to 5.815 GHz defined under EN 12253/ 5.850 to 5.925 GHz as per IEEE 802.11p)
Supported Protocols	ISO 14906, EN 12253, EN 12795, EN 12834
Operating Modes	Bidirectional, Session-based Communication with OBUs
Data Encryption	AES-128 / AES-256 or equivalent cryptographic support
Authentication	Mutual Authentication (OBU ↔ RSU)
Antenna Type	Directional or sectoral DSRC antennas, ≥12 dBi gain
Read/Communication Range	Up to 15–30 meters
Processing Capabilities	Supports session initiation, encryption, and transaction handling
Interfaces	Ethernet, RS422/RS485, CAN bus, Digital I/O
Mounting Type	Gantry-mounted / roadside pole-mounted
Ingress Protection	IP65 or higher (suitable for outdoor deployment)

Operating Temperature	-40°C to +60°C
Power Supply	24–48 VDC or 230 VAC (depending on model)
Power Consumption	≤ 20W
Dimensions	To be specified by manufacturer (typically compact units)
Weight	Varies by model (typically 3–6 kg)
Certifications	CE, FCC, EN standards (for DSRC)
Firmware Upgradeability	Supports remote/local upgrades for security patches and protocol updates
Protocol Stack Support	Compliant with ISO 14906, ISO 12813, ISO 12855 (Application Layer and Messaging)
Configuration Interface	Web-based GUI and command-line interface (CLI) over serial or network
Integration Protocols	TCP/IP, UDP socket interface for TMS integration
Diagnostic Tools	Built-in diagnostics, log retrieval, communication health monitoring
Session Logging	Records session ID, timestamp, OBU ID, event outcomes
Role-Based Access Control	Admin/user separation for device configuration and monitoring
Security Enhancements	Replay protection, nonce-based authentication, anti-cloning detection
Interoperability	Compatible with CEN DSRC OBUs and national tolling standards

DSRC = Dedicated Short Range Communication; CEN = Comité Européen de Normalisation (European Committee for Standardization); ISO = International Organization for Standardization; EN = European Norm (European Standard); OBU = On-Board Unit; RSU = Roadside Unit; AES = Advanced Encryption Standard; dBi = Decibels relative to an isotropic radiator (antenna gain); RS422/RS485 = Serial communication standards for industrial devices; CAN bus = Controller Area Network bus (vehicle communication interface); I/O = Input/Output; IP65 = Ingress Protection Rating (dust-tight and water jet resistant); VDC = Volts Direct Current; VAC = Volts Alternating Current; CE = Conformité Européenne (European conformity marking); FCC = Federal Communications Commission.

7.37.5.3. On-Board Unit (OBU)

The On-Board Unit (OBU) is a vehicle-mounted electronic device used for electronic toll collection system (ETCS) via Dedicated Short-Range Communication (DSRC). It communicates securely with the Roadside Unit (RSU) to facilitate toll transactions, typically using an embedded or inserted IC card (smart card). Although the OBU is installed by the road user, it must conform to specific technical and communication standards to ensure compatibility with the RHD Toll Management System.

Technical Specifications:

Description	Requirement
Communication Standard	DSRC compliant with ISO 14906 and CEN DSRC specifications
Operating Frequency	5.8 GHz band (5.795 to 5.815 GHz defined under EN 12253/ 5.850 to 5.925 GHz as per IEEE 802.11p)
IC Card Interface	ISO/IEC 7816 (contact) or ISO/IEC 14443 (contactless)
Security Functions	Mutual authentication, symmetric/asymmetric encryption

Transaction Support	Toll request, vehicle ID, IC card read, session key exchange
Response Time	≤ 50 ms
Memory	Sufficient to store recent transactions and card data
Data Protection	AES-128 or AES-256 encryption supported
Power Source	Vehicle battery or internal power supply (for active/semi-active OBUs)
Operating Temperature	-25°C to +70°C
Mounting Location	Inside vehicle (typically windshield or dashboard)
Tamper Resistance	Device must be sealed and uniquely coded

DSRC = Dedicated Short-Range Communication; RSU = Roadside Unit; OBU = On-Board Unit; IC = Integrated Circuit; CEN = Comité Européen de Normalisation; ISO = International Organization for Standardization; IEC = International Electrotechnical Commission; AES = Advanced Encryption Standard.

7.37.5.4. Toll Card (Toll Control Unit)

The Toll Lane Controller Unit (Toll Card) serves as the core processing device for lane-level operations and interfaces directly with the Toll Management System (TMS) of the Roads and Highways Department (RHD). It is responsible for executing toll calculation logic, managing vehicle passage, recording transactions, and monitoring lane incidents and events. Fully integrated with all toll lane subsystems, including automatic barriers, RFID readers, ANPR cameras, axle counters, vehicle detection loops, Touch & Go systems, and receipt printers, the controller ensures synchronized and secure toll collection. It stores lane-level transactional data and supports system integrity by disabling lane operations in the event of anomalies or unauthorized activities. Custom-developed by the RHD MIS Department, the unit is designed for high compatibility with RHD's national tolling framework. It can be adapted to integrate with foreign-manufactured toll equipment as required.

The Contractor shall ensure that the Toll Lane Controller Unit (Toll Card) is fully compatible with the Roads and Highways Department (RHD) Toll Management System (TMS) and shall coordinate with the RHD MIS Department for installation, configuration, and integration of all lane-level subsystems, including barriers, RFID readers, ANPR cameras, axle counters, and vehicle detection loops. The Contractor shall use only RHD-approved hardware or seek prior approval for any equivalent solutions, ensure secure and uninterrupted data exchange with the central TMS, and implement safeguards to disable lane operation in case of unauthorized access or system failure. The Contractor shall submit all relevant as-built documentation, test results, configuration files, and operational manuals, participate in end-to-end system testing as directed by the Engineer or RHD, and provide technical support, updates, and maintenance training to ensure long-term reliability and security of the toll collection system.

Technical Specifications:

Specification	Value
CPU	Intel Embedded Processor

Clock Speed	3.2 GHz
RAM	32 GB
SSD	512 TB
I/O Interfaces	USB, Serial, PCI
Ethernet LAN Port	1 (10/100/1000 Base-T)
Operating Voltage	230/50 V/Hz

7.37.5.5. Automatic Barrier Gate

Automatic Barrier Gates shall be utilized at toll plazas to manage traffic, facilitating the collection of tolls from all vehicles at the payment axis. These barriers are electromechanical, featuring an electric motor that drives a mechanical assembly.

Technical Specifications:

Specification	Value	Unit
Mains supply Voltage	230	V
Mains supply Frequency	50	Hz
Drawn power	370	W
Opening/Closing Time	0.3	Sec
Boom Profile	Round/box (Reflective stripes)	-

Note: Should be compatible with the RHD toll management system.

Automatic Lane Barriers should have an aluminum stainless cover and shall have a minimum 3 m boom length. The opening and closing times shall be a maximum of 1.2 seconds. It shall include an automatic opening in case of any obstacle under the boom when closing. The boom mounting and movement shall be capable of adjusting to either the left or right, and shall be designed with protection against vandalism. Also, it shall have protection against the hits so that the boom opens horizontally to prevent damage to the equipment. In case of power failure, it shall stay open. Control of the Barrier Gate is managed by a dedicated lane controller.

7.37.5.6. Automatic Number Plate Recognition (ANPR) Camera

The ANPR camera shall be used to capture clear images of vehicle license plates, including Bangla plates, under all lighting and weather conditions. The camera shall support real-time recognition at varying vehicle speeds and integrate seamlessly with the RHD Toll Management System.

Technical Specifications:

Description	Value / Range

Image Sensor	Minimum 1/2.8" progressive scan CMOS (supports Bangla license plates)
Resolution	At least 4 Megapixels (e.g., 2048 × 1536 or higher)
Shutter Speed	Fast shutter support, from 1/3 s to 1/100,000 s (for motion capture)
Minimum Illumination	0.07 Lux @ F1.2 (AGC ON), 0 Lux with IR
Lens	Fixed or motorized, 4 mm to 32 mm (e.g., 8 mm to 32 mm optional)
Lens Mount	M12
IR Illumination	Integrated or external IR with a minimum range of 30 meters
Wide Dynamic Range (WDR)	Minimum 120 dB
Frame Rate	25–30 fps at full resolution (2048 × 1536 or 1920 × 1080)
Bit Rate	Adjustable, 32 Kbps – 12 Mbps
Image Settings	Brightness, contrast, saturation, rotation (adjustable via browser/client)
Video Compression	H.265, H.264, MJPEG
On-Board Processing	Integrated OCR engine for edge-based ANPR processing
On-Board Storage	Supports microSD card, minimum 128 GB
Vehicle Speed Handling	Recognizes number plates at speeds up to 200 km/h
Network Protocols	TCP/IP, UDP, HTTP, HTTPS, FTP, DHCP, DNS, SNMP, RTSP, NTP, SMTP, IPv6, etc.
API Support	ONVIF compliant, and HTTP API / SDK for integration
Communication Interface	RJ45 10M/100M Ethernet; supports IEEE 802.11b/g/n wireless (range ~50m)
Channel Bandwidth	Supports 20/40 MHz
Power Supply	12 VDC ±10%, 24 VAC ±10%, or PoE (IEEE 802.3af/at)
Power Consumption	Max 15W (IR on)
Operating Temperature	–40°C to +60°C
Ingress Protection	IP67 or higher (dustproof and waterproof)
Impact Protection	IK10 (vandal-resistant housing)
Camera Housing	Weatherproof metal enclosure, suitable for outdoor installation
Certifications	CE, FCC, UL

CMOS = Complementary Metal-Oxide Semiconductor; Lux = Unit of illuminance (light level); IR = Infrared; WDR = Wide Dynamic Range; OCR = Optical Character Recognition; FPS = Frames Per Second; H.264 / H.265 / MJPEG = Video compression standards; TCP/IP = Transmission Control Protocol / Internet Protocol; PoE = Power over Ethernet; RJ45 = Registered Jack 45 (Ethernet connector); IEEE 802.11b/g/n = Wireless communication standards; API = Application Programming Interface; SDK = Software Development Kit; ONVIF = Open Network Video Interface Forum; IP67 = Ingress Protection rating (dust-tight and water-resistant); IK10 = Impact Protection rating (vandal-resistant); VDC

= Volts Direct Current; VAC = Volts Alternating Current; CE = Conformité Européenne (European conformity marking); FCC = Federal Communications Commission; UL = Underwriters Laboratories (safety certification).

7.37.5.7. Lane Incident and Overview Camera (Bullet Camera)

The Lane Incident and Overview Camera shall be installed in each toll lane to capture visual documentation of vehicles passing through. These cameras provide overview images and videos for enforcement and audit purposes, focusing on exempt vehicles, classification mismatches, and visual evidence of violations. They shall not be used for license plate recognition, but rather to supplement ANPR and tolling data by providing contextual front and side views.

Technical Specifications:

Description	Value / Range
Image Sensor	1/2.8" Progressive Scan CMOS, minimum 5 Megapixels
Minimum Illumination	Color: ≤ 0.15 Lux @ F1.2; B/W: 0 Lux with IR
Shutter Speed	1/25 s to 1/100,000 s
Wide Dynamic Range (WDR)	≥ 120 dB
Lens Type	Varifocal lens, 3 mm to 7.37 mm focal length
Aperture	F1.4 maximum
Field of View (FOV)	Horizontal: 88°–36°; Vertical: 50°–23° (adjustable)
IR Illumination	Integrated IR, minimum range 30 meters
IR Cut Filter	Automatic switch (Day/Night mode)
IR Range	Up to 30 meters
Maximum Resolution	3072 × 1728 / 2592 × 1944 / 2560 × 1920 (minimum 5 MP)
Video Streams	Minimum two (02) streams (Mainstream up to 5 MP @ 25/30 fps)
Frame Rate	25–30 fps (dependent on resolution)
Video Compression	H.265 / H.264 / MJPEG
Audio Compression	G.711 / G.726 / MP2L2 / PCM / MP3 / AAC
Audio Sampling Rate	8 kHz / 16 kHz / 48 kHz
Region of Interest (ROI)	Supported (On/Off)
Basic Event Detection	Motion Detection, Tamper Detection
Image Settings	Brightness, Contrast, Saturation, Rotate (configurable via web or software)
Signal-to-Noise Ratio (SNR)	> 55 dB
On-Board Storage	Micro SD card supported (min. 128 GB recommended)
API Support	ONVIF compliant, supports HTTP API or SDK
Network Protocols	IPv4, IPv6, TCP, UDP, HTTP, HTTPS, RTP, RTSP, RTCP, FTP, DHCP, DNS, NTP, SNMP, SMTP, ICMP, IGMP, 802.1X, QoS, Bonjour

Communication Interface	RJ-45 Ethernet (10/100 Base-T), IEEE 802.11b/g/n wireless
Channel Bandwidth	Supports 20/40 MHz
Wireless Range	Up to 50 meters (depending on environment)
Power Supply	12 VDC $\pm 10\%$, 24 VAC $\pm 10\%$, or PoE (IEEE 802.3af/at)
Power Consumption	Max. 15 Watts (including IR and audio features)
Operating Temperature	-43°C to +60°C
Humidity	$\leq 95\%$ RH (non-condensing)
Weatherproof Rating	IP67 (dust- and water-resistant)
Impact Protection	IK10 (vandal-resistant metal housing)
Camera Body Material	Metal (outdoor weatherproof housing)
Certifications	CE, UL, FCC

CMOS = Complementary Metal-Oxide Semiconductor; Lux = Unit of illuminance (light intensity); IR = Infrared (used for night vision); WDR = Wide Dynamic Range; FOV = Field of View; FPS = Frames Per Second; ROI = Region of Interest; H.264 / H.265 / MJPEG = Video compression standards; SNR = Signal-to Noise Ratio; PoE = Power over Ethernet; RJ-45 = Registered Jack 45 (Ethernet connector); IEEE = Institute of Electrical and Electronics Engineers; ONVIF = Open Network Video Interface Forum; API = Application Programming Interface; SDK = Software Development Kit; IP67 = Ingress Protection (dust-tight and water-resistant up to 1m depth); IK10 = Impact Protection (resistant to 20-joule mechanical impact); VDC = Volts Direct Current; VAC = Volts Alternating Current; CE = Conformité Européenne; UL = Underwriters Laboratories; FCC = Federal Communications Commission.

7.37.5.8. Booth Surveillance Dome Camera (IP)

The Booth Dome Camera shall be installed inside each toll booth to enable continuous monitoring and auditing of toll collection, cash handling, customer service, and overall booth activities. The camera shall provide high-definition video, even under low-light conditions, and be equipped with features suitable for 24/7 security surveillance, including IR, motion detection, and onboard storage.

Technical Specifications:

Description	Value / Range
Camera Type	Fixed IP Dome Camera with lens, dome housing, and mounting accessories
Image Sensor	1/2.8" Progressive Scan CMOS
Resolution	Minimum 5 MP (e.g., 2592 $\times$ 1944 or higher)
Minimum Illumination	Color: ≤ 0.185 Lux @ F1.3; B/W: 0 Lux with IR
Shutter Speed	1/25 s to 1/15,000 s
Lens Type	Varifocal lens, 2.8 mm to 12 mm
Aperture	F1.4 or better
Field of View (FOV)	Horizontal: 95°–30°; Vertical: 50°–20° or better
Day/Night Mode	True Day/Night with Automatic IR Cut Filter (ICR)
IR Range	Minimum 30 meters

Wide Dynamic Range (WDR)	≥ 120 dB
Video Compression	H.265 / H.264 / MJPEG
Video Streams	Dual stream (Mainstream: 5 MP @ 25/30 fps)
Audio Compression	G.711 / G.726 / MP2L2 / PCM / MP3 / AAC
Audio Sampling Rate	8 kHz / 16 kHz / 48 kHz
Motion Detection	Supported with adjustable sensitivity
On-Board Storage	MicroSD slot (supports minimum 128 GB)
Network Interface	RJ-45 (10/100 Base-T Ethernet), IEEE 802.3af/at PoE
Supported Protocols	IPv4, IPv6, HTTP, HTTPS, TCP/IP, UDP, FTP, NTP, DNS, DHCP, SMTP, SNMP, RTP/RTCP, ICMP, IGMP
API Support	ONVIF compliant
Power Supply	12 V DC ±10%, 24 V AC ±10%, or PoE
Power Consumption	Max. 15 W
Housing Material	Metal
Ingress Protection	IP67 (dust- and water-resistant)
Impact Protection	IK10 (vandal-resistant)
Operating Temperature	–40°C to +50°C
Operating Humidity	10% to 90% RH (non-condensing)

CMOS = Complementary Metal-Oxide Semiconductor; Lux = Unit of light intensity; IR = Infrared; FOV = Field of View; WDR = Wide Dynamic Range; ICR = Infrared Cut Removable filter (for day/night mode); FPS = Frames Per Second; H.264 / H.265 / MJPEG = Video compression formats; G.711 / G.726 / MP2L2 / PCM / AAC = Audio compression formats; PoE = Power over Ethernet; RJ-45 = Registered Jack 45 (Ethernet); ONVIF = Open Network Video Interface Forum; API = Application Programming Interface; IP67 = Ingress Protection rating (dust-tight and waterproof up to 1m); IK10 = Impact Protection rating (resistant to 20-joule impact); VDC = Volts Direct Current; VAC = Volts Alternating Current; CE = Conformité Européenne (European Conformity); FCC = Federal Communications Commission; UL = Underwriters Laboratories.

7.37.5.9. Inductive LOOP Sensor

Inductive loop sensors shall be used for accurate vehicle detection and direction sensing in each toll lane. The system shall be capable of detecting vehicle presence and movement direction, and shall serve as a trigger for toll transaction events, such as barrier activation, camera capture, and classification processing.

Inductive loop sensors shall be installed in each toll lane to enable accurate vehicle detection, presence confirmation, and direction sensing. These loops shall be embedded in the pavement and connected to a multi-channel inductive loop controller. Two specific loop functions shall be supported:

- **Presence Loop:** Installed in the transaction zone to detect vehicle presence and initiate transaction-related processes (e.g., classification, camera capture, toll computation).
- **Exit Loop:** Installed at the end of the lane to detect when the vehicle exits the transaction zone and to trigger the automatic opening of the exit barrier after successful toll payment.

The system shall provide Level A accuracy as defined in Section 7.39.35 of the Automatic Traffic Counter and Classifier standards. It shall be calibrated and tested to ensure consistent and reliable performance under all environmental conditions.

Technical Specifications:

Description	Value or range
Loop Configuration	Minimum 2 loops per card; presence and exit loop support
Sensitivity Levels	Minimum of 4 adjustable levels
Frequency Settings	Minimum of 4 adjustable frequency levels
Indicators	LED indicators for vehicle presence, loop activation status, and loop failure
Pulse Relay Selection	The Pulse Relay may be configured to energize on detection of a vehicle or when the vehicle leaves the loop
Boost function	This feature sets the undetected level to maximum sensitivity
Reset Switch	The reset switch enables the detector to be manually reset during commissioning and testing These result in the detector re-tuning the sensing loop and becoming ready for vehicle detection
Compatibility	Fully compatible with toll barrier systems, cameras, AVC, and lane controllers
Installation	Embedded pavement installation with sealed connections

7.37.5.10. AVC (Automatic Vehicle Classifier) Sensors

Axle sensors shall be deployed in each toll lane as part of the Automatic Vehicle Classification (AVC) system. These sensors shall accurately detect and record the number of axles, axle spacing, and axle groupings for all passing vehicles. The system shall enable precise vehicle classification based on these parameters.

In addition, a height detection sensor, either integrated or separately installed, shall measure both the height above the first axle and the overall vehicle height. This combined data shall support enforcement and ensure accurate toll rate application according to the predefined vehicle classification rules.

Technical Specifications:

Specification	Value	Unit
Scanning Range	20	Meter
Light Spot Diameter	950	nm
Operating Voltage	10-30	VDC
Operating Current	100	mA

Signal Sequence Min.	1000	Per sec
Response Time	750	ms
Installation Type	Outdoor	
Enclosure Rating	IP 68	
Operating Temperature	-20 to +70	Degrees
Operating Humidity (RH)	90	%
Standard Compliance	CE	

7.37.5.11. Toll Lane Monitor

The Toll Lane Monitor shall serve as the primary visual interface for the toll collector within each toll booth. It shall provide a graphical user interface (GUI) for real-time monitoring of lane activity, vehicle classification, transaction status, and toll collection operations. The monitor shall be compatible with the Toll Lane Controller and display high-resolution video feeds, vehicle information, and system alerts. It shall support ergonomic, 24/7 operation under varying lighting conditions and include user-configurable display settings.

Technical Specifications:

Specification	Value
Display Size	24" W
Display Type	LED
Panel Type	VA
Resolution	Full HD (1920 x 1080)
Pixel Pitch (MM)	0.2745 (H) x 0.2745 (V)
Display Surface	Anti-glare
Aspect Ratio	16:9
Viewing Angle	178 (H) / 178 (V)
Contrast Ratio	3000:1
Refresh Rate	75Hz
Color Support	16.7M
Color Gamut	sRGB: 105% (CIE 1976)
Response Time	4ms (GTG)
Curvature	Flat
HDMI	1 x HDMI (1.4b)
D-Sub	1 x D-Sub (VGA)
Dimension	541.79 x 46.61 x 180.8mm
Power Type	External Adaptor (12V 2.5A)

VA = Vertical Alignment (a type of LED panel technology); FHD = Full High Definition (1920 × 1080 resolution); MM = Millimeters; sRGB = Standard Red Green Blue (color space standard); CIE = Commission Internationale de l'Éclairage (International Commission on Illumination); GTG = Grey-to-Grey (response time measurement); HDMI = High-Definition Multimedia Interface; D-Sub = D-subminiature connector (commonly VGA); VGA = Video Graphics Array; Hz = Hertz (unit of refresh rate); ms = Milliseconds (unit of response time); LED = Light Emitting Diode; W = Width (inches); DC = Direct Current; Adaptor = External power supply converter.

7.37.5.12. Receipt Printer

The receipt printer shall be a compact thermal printing device integrated with the smart card/EMV-compliant card reader and controlled by the Toll Lane Controller. It shall be used to generate toll payment receipts, barcodes, and relevant system status messages for road users. The printer shall support high-speed, reliable operation, automatic cutting, and compatibility with industry-standard receipt formats. It shall also be capable of operating in toll booth environments with continuous daily use.

Technical Specifications:

S.N.	Specification	Value
1	Printing Method	Direct Thermal
2	Printing Speed	200
3	Font	9 x 17/12 x 24
4	Print Resolution	203 x 203 dpi
5	Auto Cutter	Fully automatic
6	Internal Buffer	Receive: 45 bytes or 4KB
7	Barcode Support	UPC-A/E, CODE 39/93/128, EAN8/13, ITF, CODABAR, QR-Code
8	Driver Compatibility	EPSON DRIVER Compatible
9	MTBF	360,000 hours
10	MCBF	52,000,000 lines
11	Auto Cutter Life	1.5 million cuts
12	Character Size	0.99(W) x 2.4(H)
13	Characters Per Line	Font A(12*24) 42 columns
14	Paper Dimensions	3.13" ± 0.02" x 3.27" diameter
15	Cash Drawer Support	Yes
16	EMI Standards	FCC/ICES-003 Class A
17	Brand	To be determined by the Engineer

Direct Thermal = printing technology that uses heat-sensitive paper without ink or ribbon; dpi = dots per inch (resolution unit); Auto Cutter = mechanism for automatic paper cutting; Buffer = memory used to temporarily store print data; UPC, CODE 39/93/128, EAN, ITF, CODABAR, QR-Code = barcode formats supported; EPSON DRIVER Compatible = compatible with Epson standard printer drivers; MTBF = Mean Time Between Failures (device reliability measure); MCBF = Mean Cycles Between Failures (print mechanism durability); EMI = Electromagnetic Interference; FCC = Federal Communications Commission (US compliance); ICES-003 = Canadian EMI standard; Font A = predefined font size format; Paper Dimensions = physical width and diameter of roll; Cash Drawer Support = printer can trigger external cash drawer.

7.37.5.13. Touch & Go

The Touch & Go device shall be a passive RFID sticker embedded with a secure radio frequency identification chip. It shall be affixed to the vehicle's windshield or headlamp and enable seamless, contactless toll payment by interacting with RFID readers installed in designated toll lanes. The device

shall store a unique identifier linked to the user's toll account and support automated vehicle identification, reducing queue times and enhancing throughput in RFID-enabled lanes.

Technical Specifications:

Description	Value or range
Scanner Type	Bi-directional linear imager or 2D area imager
Supported Symbolologies	1D: UPC/EAN, Code 39, Code 128, Codabar, ITF, MSI; 2D: QR Code, PDF417, DataMatrix
Light Source	Visible red LED (625–650 nm)
Scan Rate	Minimum 100 scans/sec (linear); 60 fps (area imager)
Reading Distance	2 cm to 45 cm (typical for printed cards or labels)
Print Contrast (Minimum)	20% reflective difference
Motion Tolerance	Up to 2.5 m/s (for drive-through validation)
Pitch / Skew / Roll Tolerance	$\pm 65^\circ$ / $\pm 60^\circ$ / $\pm 30^\circ$
Interface Options	USB, RS232, Keyboard Wedge, Ethernet (optional)
Power Source	5V DC $\pm 10\%$ via host (USB/RS232) or external adapter
Power Consumption	≤ 2.5 W (typical operation)
Environmental Protection	IP54 or higher (dust and splash resistant)
Operating Temperature	0°C to +50°C
Storage Temperature	-40°C to +70°C
Operating Humidity	5% to 95% RH (non-condensing)
Drop Resistance	Withstands drops from 1.5 m onto concrete
Certification	CE, FCC, RoHS compliant
Integration	Fully compatible with RHD Toll Management System
Mounting	Handheld or fixed mount with stand (as per booth configuration)

RS232 = Serial Communication Port; IP54 = Ingress Protection (dust/splash); CE = Conformité Européenne; FCC = Federal Communications Commission; RH = Relative Humidity; RoHS = Restriction of Hazardous Substances.

7.37.5.14. Traffic Light

The toll lane traffic light shall be installed at the entry or exit point of each toll lane to regulate vehicle movement based on transaction status. It shall provide clear visual signals, typically red to indicate stop and green to indicate proceed, corresponding to the completion or failure of the toll transaction. The traffic signal shall be electronically synchronized with the barrier gate and Toll Lane Controller to ensure safe and efficient vehicle passage. It shall remain clearly visible under all lighting conditions and operate reliably in outdoor environments.

Technical Specifications:

Specification	Value

Technology	LED Based
Installation Location	At the toll lane towards the exit side
Controlled by	TLC
Mounting	On pole, 2 meters above the road.
Side	on the right side of each lane
Synchronization with	Boom Barrier Traffic light Green, barrier open. Traffic light Red, barrier closed.
Size of the display	200mm diameter with visor
Visibility	>100 meters under normal conditions
LED	2 aspects: red/green
Housing	Polycarbonate
Dimensions	200mm diameter of Red LEDs Aspect and 200mm diameter for Green LEDs Aspect.
Weight	3 kg approx.
Night dimming	Photo sensor for automatic night dimming feature (Optional)
Led Intensity	(Red color) minimum luminance of 3000cd/m2 (Green color) minimum luminance of 4000cd/m2
wavelength	630nm (red) and 526nm (green).
Power Supply	230V AC / 50Hz
Humidity	95 % Rh
Power Consumption	8 W each aspect
Interface	2 separate 230 Vac. Input for Red and Green. By means of screw type terminals.
MTBF/ MTRR	100,000 Hrs. /30-minute exchange
Enclosure Environmental protection	IP 66 (LEDs sealed Retrofit Kit)
Electronic components	Industrial-grade components and connectors

7.37.5.15. Overhead Lane Sign (OHLS)

The Overhead Lane Sign (OHLS) shall be installed on the leading edge of the toll plaza canopy, directly above each toll lane, to clearly indicate the operational status of the lane to approaching motorists. The sign shall display distinct red and green visual indicators, such as a Red Cross (lane closed) and a Green Arrow (lane open), or solid red and green aspects. The OHLS shall be visible from a minimum specified distance and operate in synchronization with the toll lane control system to provide real-time lane status, aiding in efficient lane selection and safety.

Technical Specifications:

Specification	Value
Technology	LED
Colors	Red, Green
Red LEDs Intensity	8000mcd

Green LEDs Intensity	12000mcd
Visibility	300 m
Wavelength	Red - 625nm, Green - 505nm
Enclosure Material	Polycarbonate
LED Aspect Dimensions	300mm diameter
Weight	3 kg approx.
Hood	Sun hood
Mounting	Leading edge of the canopy above the lane center
Lane Closed Indicator	Red Cross
Lane Open Indicator	Green Arrow
Enclosure Protection	IP 66 (LEDs sealed Retrofit Kit)
Electronic Components	Industrial-grade components and connectors
Power Consumption	18 W approx.
Interfacing Details	Two separate lines for Green Arrow & Red Cross, with common Neutral & Earth
MTBF	100,000 Hrs
MTRR	30-minute exchange
Humidity	95% RH

7.37.5.16. Lane and Plaza Network Switch

The Lane and Plaza Network Switch shall serve as the core data communication device between individual toll lanes, booths, plaza tunnel areas, and the Toll Plaza Server Room. The switch shall provide high-speed, secure, and reliable connectivity for all lane-level equipment, including controllers, cameras, sensors, and toll collection systems. Installed within the toll booth or tunnel enclosures, the network switch shall support multiple Ethernet interfaces, enable seamless data aggregation, and ensure uninterrupted communication within the Toll Management System infrastructure.

Technical Specifications:

Specification	Description
Ports	24 × 10/100/1000 Mbps RJ-45, 4 × 1G/10G SFP+ slots (fiber uplinks)
Full/Half Duplex	Full duplex for Gigabit; Auto-negotiation for 10/100 Mbps
Switching Capacity	128 Gbps or higher
MAC Address Table	Minimum 32,000 entries
MAC Address Update	Supports static, dynamic, and secure MAC entries
Packet Forwarding Rate	Minimum 95 Mpps (Million packets per second)
Packet Buffer Memory	Minimum 4 MB
Interfaces	24 × RJ-45 Ethernet; 4 × SFP+ (Mini-GBIC), Console port, USB
Layer Support	Layer 2 and Layer 3 Lite with VLAN, ACL, QoS, IGMP Snooping

MTBF	≥ 1,000,000 hours
Redundancy Features	Dual power supply (optional), Spanning Tree, RSTP, VRRP
Power	AC 100–240V, 50/60 Hz internal PSU
Power Consumption	≤ 30W (typical switching load)
Port Standards & Functions	IEEE 802.3, 802.3u, 802.3ab, 802.3az (Energy Efficient Ethernet), PoE (optional)
Server Storage	≥ 1 TB SSD (solid-state drive)
Optical Drive	External USB DVD (optional, legacy support)
Keyboard & Mouse	USB interface, included
Rear Ports	≥ 4 × USB 3.0, 2 × USB 2.0, Serial, RJ-45, DisplayPort, Audio in/out
Audio	Integrated high-definition audio
Networking	Integrated 10/100/1000 Mbps NIC with PXE boot
Operating System	Windows 10 Professional 64-bit or Linux (Ubuntu/CentOS)
Antivirus	Pre-installed commercial antivirus with 1-year license
Power Supply Unit	350W, 90% efficient, Active PFC
Operating Voltage & Frequency	230V ±10%, 50/60 Hz
Operating Temperature	10°C to 40°C
Operating Humidity	5% to 85% RH (non-condensing)
Compliance	CE, FCC, RoHS, IEC 60950

RJ-45 = Registered Jack 45 (Ethernet connector); SFP+ = Small Form-factor Pluggable Plus (fiber module); Gbps = Gigabits per second; Mbps = Megabits per second; MTBF = Mean Time Between Failures; VLAN = Virtual LAN; ACL = Access Control List; QoS = Quality of Service; VRRP = Virtual Router Redundancy Protocol; PSU = Power Supply Unit; NIC = Network Interface Card; PXE = Preboot Execution Environment; SSD = Solid-State Drive; PFC = Power Factor Correction; IEC = International Electrotechnical Commission; CE = Conformité Européenne; FCC = Federal Communications Commission; RoHS = Restriction of Hazardous Substances.

7.37.5.17. Network Laser Printer

The Network Laser Printer shall be a high-speed, heavy-duty printing device installed in the toll plaza back office or control room, designed to support centralized printing requirements for toll operations. It shall be capable of producing toll receipts, reports, transaction logs, system summaries, and other administrative documents. The printer shall support network connectivity (Ethernet) to integrate with the Toll Management System and allow remote access from multiple workstations across the plaza network. It shall deliver reliable, high-volume performance with low maintenance requirements.

Technical Specifications:

Specification	Description
Print Speed (Black)	Up to 26 ppm (Letter), up to 25 ppm (A4)
First Page Out (Ready)	As fast as 8 seconds
Print Resolution (Best)	Up to 600 × 600 × 2 dpi (1200 dpi effective output)
Print Resolution (Normal)	Up to 600 × 600 dpi
Print Technology	Laser
Resolution Technologies	HP FastRes 1200, 600 dpi
Standard Connectivity	1 × Hi-Speed USB 2.0, 1 × Ethernet 10/100

Network Ready	Yes (built-in Ethernet)
Network Capabilities	10/100 Ethernet
Memory	128 MB
Processor Speed	750 MHz
Output Capacity	150-sheet output tray
Media Sizes Supported	A4, A5, A6, B5, B6, Letter, Legal, Executive, Postcards, Envelopes (No.10, Monarch)
Power Input Voltage	110–127 VAC ($\pm 10\%$), 60 Hz (± 2 Hz)
Power Consumption	450 W (active), 2.2 W (ready/sleep), 0.1 W (Auto-Off/Manual-Off)
Operating Temperature Range	15°C to 32.5°C

ppm = pages per minute; dpi = dots per inch (print resolution); Ethernet = wired network interface; VAC = Volts Alternating Current;

7.37.5.18. P10 LED for Lane Fare Display

The P10 LED Lane Fare Display shall be used to provide real-time toll fare information for each toll lane. It shall ensure clear visibility to approaching drivers under various lighting and weather conditions, with support for wide viewing angles and programmable display formats. The display shall be remotely configurable, integrate with the Toll Management System, and support multiple connectivity options for dynamic toll rate updates based on vehicle classification, payment method, or operational conditions.

Technical Specifications:

Description	Value or Range
Screen Size	22 inch (47 cm)
Type of Television	LED
Resolution (Pixels)	1366 x 768
Aspect Ratio	16:9
Brightness	300 cd/m ²
Response Time	7ms
Picture Mode	Standard, Eco, Movie, Vivid, Personal
Color Temperature	Normal, Cool, Warm
USB Port	2
Dynamic Contrast Ratio	Yes
Dynamic Color Control	Yes
3D Comb Filter	Yes
Picture Format	Wide, Normal, Zoom1, Zoom2
Backlight Control	Yes
Sound Mode	Standard, Speech, Music, Personal
TV RF Input	Input x 1

AV Input	Input x 1
YPbPr Input	Input x 1
USB Input	Input x 1 (Movie, Music & Photo)
PC Input	Input x 1
PC Audio Input	Input x 1
Video Output	Output x 1
Power Supply	100 – 240 V AC, 50/60 Hz

7.37.5.19. Desktop-Mounted Barcode Reader for Toll Booths

The barcode reader (BCR) shall be installed on the toll collector's desk inside each manual or semi-automatic toll booth. It shall be a high-performance, fixed desktop-mounted 2D area imager capable of scanning both printed and digital barcodes (e.g., mobile device screens) for validating return and daily pass tickets. The BCR shall provide fast, hands-free, and omnidirectional scanning with advanced decoding capability to ensure accurate reading even under low light or suboptimal barcode conditions. It shall interface directly with the Lane Controller to retrieve transit information from the barcode and validate the associated vehicle class in real time for secure and efficient transaction processing. The unit shall support continuous 24×7 operation with minimal maintenance and rapid wake-up from sleep mode through proximity sensing or manual activation.

Technical Specifications:

Description	Specification
Type	Desktop-mounted fixed 2D area imager barcode reader for toll booth use
Scanning Technology	CMOS-based high-speed image sensor
Barcode Support	1D and 2D barcodes including QR Code, PDF417, Data Matrix, Aztec, EAN/UPC
Digital Media Support	Capable of reading barcodes from printed tickets and digital displays (e.g., smartphones, tablets)
Image Capture	Real-time image decoding with advanced error correction
Scan Speed	≥ 60 frames per second
Depth of Field	50 mm to 500 mm (depending on barcode size and contrast)
Lighting	Built-in white and infrared (IR) illumination with auto exposure control
Operation Mode	Fully automatic scanning with configurable sleep mode
Reactivation	Proximity sensor or push-button wake-up
Interface	USB 2.0/3.0 or RS-232 (plug-and-play)
Dimensions	Max 152 mm (H) × 152 mm (W) × 91 mm (D)
Weight	≤ 500 g
Durability	≥ 50,000 hours MTBF; suitable for continuous use

7.37.5.20. Equipment cabinets

Any edge processing unit or electronics for the toll plaza shall be installed in an outdoor equipment cabinet, designed to safely protect sensitive components from environmental hazards, vandalism, and electrical interference. The cabinet shall comply with the following specifications:

A. Construction and Protection Requirements

- Outdoor-rated, IP66-rated for dust and weatherproofing; corrosion and rust-resistant.
- Welded design ensuring strength, rigidity, and durability.
- High-grade polyurethane door joint strip for environmental sealing.
- Corrosion protection and appropriate surface treatment matching the installation environment.
- Painted and uniquely numbered in line with its respective toll lane and function, to enable clear reporting to the plaza software subsystem.

B. Security and Monitoring

- Vandalism-proof construction, housed within a secure, fenced environment.
- 3-point locking mechanism with a unique key for access control.
- Equipped with an external alarm system connected to the Toll Plaza Operator Room and Main Control Center. Alarms include:
 - Door open
 - Intrusion detection
 - Environmental alarms (optional)
- Proximity-based door monitoring: All door open/close events shall be timestamped and logged by lane in the toll plaza software system as incidents.

C. Cable Management and Safety

- All cables (signal & power) shall be properly routed using internal railings, with vertical cable management rings on both sides of the rack.
- Cable glands with removable rubber covers shall be located at the cabinet base for weatherproof entry.
- Separate routing of power and signal cables to ensure easy fault tracing and quick replacement.
- Proper screening and shielding of all external data cables for protection from lightning and EMI.
- Numbered terminations for all signal and power cables at:
 - The controller end
 - Manholes and junctions

- Peripheral connection points
- Labeling of all component boards for quick identification and maintenance.

D. Internal Layout and Features

- Cabinet must be sized to accommodate all equipment required for that location.
- Includes adjustable 19-inch rackmount rails for modularity.
- Equipped with /100M Ethernet ports and all accessories for data and power connectivity.
- An earthing bar shall be conveniently located near the front for safety compliance.

E. Environmental Management

- Adequate ventilation or thermal management solutions (e.g., fan or heat exchanger) shall be provided to maintain the equipment at a temperature consistent with the manufacturer's recommendations.

7.37.5.21. Uninterrupted Power Supply

The UPS units shall be of Online Uninterruptible Power Supply (UPS) type, designed to provide continuous, stable, and clean power to connected equipment. Each UPS system shall include a central processing unit (CPU) and be capable of operating with an input supply of 160 – 275V AC, single phase, 50 Hz, and deliver an output voltage of $220V \pm 1\%$, 50 Hz, single phase.

The systems shall include built-in protection features for:

- Lightning and surge protection
- Blackouts and power failures
- Over-voltage and under-voltage
- Overload conditions
- Battery under-voltage and overcharge protection

Each UPS shall provide a minimum backup time of 30 minutes at full load. The units must be complete with necessary batteries, cabling, and accessories for proper installation and operation.

7.37.5.22. Intercom and Public Address (PA) Communication System

A fully integrated Intercom and Public Address (PA) Communication System shall be installed at the Toll Plaza to enable seamless, secure, and independent voice communication between the Fee Collectors at the booths, the supervisory personnel in the control room, and other designated areas within the plaza building.

The system shall support the following minimum features:

- **Two-way hands-free communication** between the Fee Collector in each toll booth and the supervisory staff in the control room.
- A **call initiation button** on each Intercom Slave Communication Unit (ISCU), enabling the Fee Collector to alert the control room staff.
- **Remote monitoring** of booth conversations (between the Fee Collector and the road user) by the control room without notification to the booth staff.
- **Independent operation** from the main toll lane control system (i.e., HLC).
- Provision of **PA broadcast functionality**, allowing one-way communication from the control room to all lanes and booths simultaneously.
- Extension of voice communication to **building access points, auditor room, supervisor cabins, and equipment rooms** inside the plaza building.
- The system shall be scalable and modular to support future expansion of lanes or buildings.
- All components shall be industrial grade, tamper-proof, and weather-protected as per installation location.

Technical Specifications:

Intercom Slave Communication Unit (ISCU) – Lane Booth

- Hands-free operation with built-in speaker and microphone.
- Push-button to initiate a call to the control room.
- LED indicator for call status.
- Compact, rugged enclosure (IP65-rated) suitable for booth environment.
- Wall or console mountable.
- Powered via PoE or 12V DC.
- Operating temperature: -10°C to $+55^{\circ}\text{C}$.

Intercom Master Communication Unit – Control Room

- Centralized master unit capable of connecting to all slave units (booths and building rooms).
- Equipped with 10 or 20 dedicated buttons, each corresponding to a specific slave unit/lane.
- Allows individual booth communication, remote monitoring, and all-lane broadcast.
- Integrated speaker and gooseneck microphone.
- LCD display for channel indication and call status.
- Built-in amplifier, network connectivity, and recording support (if applicable).
- Desktop mountable, powered via AC supply with battery backup option.

PA System (Optional Integration)

- One-way PA broadcast capability from the master unit to all slave units.
- Option to connect external PA horn speakers in common building areas.
- Volume control per zone and emergency override.

7.37.5.23. Emergency Footswitch Alarm System

An Emergency Footswitch Alarm System shall be provided in each toll booth as a security feature to ensure the safety of the Fee Collector during emergency or high-risk situations. The system shall enable discreet triggering of an alert to the control room and activate a visual and audible warning to deter potential threats or notify supervisory personnel of an emergency.

System Functionality

- A **foot-operated emergency switch** shall be securely installed beneath the Fee Collector's workstation in each toll booth, allowing discreet activation using the foot.
- Upon activation, the system shall:
 - Send an alarm signal to the plaza control room via the Lane Status Display Unit (LSDU) or equivalent interface.
 - **Trigger a high-decibel siren** mounted externally on top of the toll booth to draw immediate attention.
- The siren may also be configured to activate under other predefined events such as **lane violations** or **convoy (VIP/military) movement**, as defined in the Toll Plaza design requirements.
- The system shall function independently of the main toll collection system to ensure uninterrupted operation in emergency situations.

Technical Specifications:

Emergency Footswitch

- **Installation Location:** Fixed on the booth floor beneath the desktop, positioned for easy foot access.
- **Material:** Heavy-duty steel construction with anti-slip surface.
- **Power Supply:** 220–240 V AC, 50–60 Hz, with integrated 10A protection.
- **Signal Interface:** Connected to the lane controller input (DI board) via termination block.
- **Mounting:** Anchored securely to prevent displacement during regular operation.
- **Design:** Modular “plug-and-replace” structure allowing rapid replacement during faults.
- **Environmental Performance:** Operating temperature range 0°C to 50°C; humidity up to 90% RH, non-condensing.
- **Reliability:** Minimum 100,000 operations MCBF; MTTR not exceeding 30 minutes.

Siren

- **Mounting Location:** Exterior top surface of the toll booth canopy or structure.
- **Type:** Motor-driven or electronic horn type.
- **Sound Pressure Level:** Minimum 112 dB at a distance of 1 meter.
- **Environmental Protection:** Weather-resistant housing; suitable for continuous outdoor use.
- **Alert Activation:** Triggered via emergency footswitch or other programmable triggers from the Toll Management System.
- **Color and Visibility:** Brightly colored housing (red or yellow preferred) with optional integrated strobe light.

7.37.5.24. Hazard Warning Light (Beacon) – Toll Booth Front

Hazard warning lights shall be installed at the upstream end of each toll booth island to alert approaching drivers during adverse weather, low visibility, system malfunctions, or when the lane is closed or under maintenance. These lights shall serve as a **visual safety alert**, especially in **nighttime or foggy conditions**, without causing glare or confusion.

Technical Specifications:

- **Type:** LED-based amber flashing beacon or rotating warning light
- **Light Output:** Minimum **120 cd luminous intensity** with **360° horizontal visibility**
- **Flash Frequency:** **60–90 flashes per minute**, adjustable; shall avoid driver discomfort or seizure risks
- **Light Source:** High-brightness, energy-efficient **LED array** with a minimum rated lifespan of 50,000 hours
- **Color:** Amber (Yellow), compliant with international road safety norms
- **Mounting Location:** On top of the toll island nose barrier, facing oncoming traffic, at a visible height of **1.0–1.5 meters**
- **Enclosure Rating:** **IP65 or higher**, weatherproof and dustproof for outdoor use
- **Material:** UV-stabilized polycarbonate dome; corrosion-resistant aluminum or powder-coated steel base
- **Power Supply:** 12/24V DC (for integration with toll booth UPS), or 230V AC with auto step-down converter
- **Control Integration:** Triggered automatically in coordination with:
 - Toll lane closure status
 - System alarms (e.g., emergency footswitch, barrier failure, violation)
 - Manual activation by the operator from the control panel
- **Operation Modes:**
 - Flashing mode (default)

- Steady-on mode (for emergency/manual override)
- **Maintenance:** Tool-free access for LED module replacement; plug-and-play design for fast servicing
- **Temperature Range:** –10°C to +60°C
- **Compliance:** CE, RoHS, and EN 12352 (Flashing Warning Light Standard) or equivalent

7.37.5.25. Control Room Equipment

To ensure continuous surveillance and security across toll plaza operations, the following control room equipment and integrated CCTV components shall be provided, installed, and commissioned. The system shall be compatible with the Toll Management Software (TMS) and the Network Video Recorder (NVR) for centralized monitoring, video analytics, and event-based recording.

Toll Management System (TMS) Workstation

Workstations shall be provided for toll supervisors and administrators to monitor video feeds, access TMS functions, review system logs, and perform audits. Each workstation shall include a minimum Intel Core i5 processor (2.4 GHz), 4 GB RAM, 300 GB storage, 17.37" LED monitor, USB keyboard and mouse, integrated NIC, and licensed antivirus software. Units shall be preconfigured and fully integrated with the TMS network.

CCTV Monitoring Display (65" 4K UHD, 24/7 Rated)

A 65" 4K UHD industrial-grade LED display shall be installed in the control room for 24×7 CCTV monitoring. The display shall support a resolution of 3840×2160, brightness of ≥ 500 cd/m², HDR, anti-glare coating, and a minimum 60,000-hour lifespan. Inputs shall include HDMI, DisplayPort, USB-C, VGA, and DVI. Supplied with a wall mount and necessary cabling for integration.

CCTV Cameras and Integration

High-resolution IP cameras shall be deployed throughout the toll plaza to monitor lanes, booths, tunnel areas, and perimeter zones. Cameras shall include fixed dome and PTZ types with a minimum 2 MP resolution, H.265 compression, wide dynamic range (WDR ≥ 120 dB), IR night vision, and ONVIF compliance. All outdoor cameras shall be IP66/IP67 rated and vandal-resistant (IK10). Power shall be via PoE or 12V DC. Camera feeds shall be streamed to the NVR for recording and be accessible via the TMS for live view, playback, and event-tagged audit. Video evidence shall be linked to toll events such as violations, classification errors, emergency triggers, or manual reviews. Integration shall include remote configuration and firmware management from the control room.

Control Room Console Desk and Chair

Ergonomic furniture shall be provided for operators and supervisors to support 24×7 operations. This shall include modular console desks with cable management, monitor mounting brackets, and a scratch-resistant surface, sized to accommodate dual-monitor setups and TMS workstation equipment. Chairs shall be high-back, adjustable, with lumbar support, armrests, and certified for continuous (24×7) control room use.

UPS Backup for Control Room Equipment

An online UPS system shall be provided to ensure uninterrupted power to control room equipment, including TMS workstations, CCTV display, NVR, and networking devices. The UPS shall be a minimum of 5 kVA with 30-minute battery backup at full load. It shall support an input voltage range of 160–275V AC, output regulation of $\pm 1\%$, and protection features including surge suppression, over/under voltage, and battery management. Remote monitoring and SNMP communication shall be supported.

7.37.5.26. Toll Plaza Server (with OS)

Toll Plaza server shall meet the following specifications or equivalent minimum:

Supply, installation, testing & commissioning of the server with specifications or equivalent as per the direction of the Engineer in charge.

- **Processors:** Two (2) Intel® Xeon® Scalable Processors, minimum clock speed of 2.6 GHz, minimum 24 cores per CPU; support for up to 64 cores per socket (latest 4th Gen Xeon or equivalent).
- **Cache:** Minimum 36 MB L3 cache per processor.
- **Chipset:** Compatible with the latest Intel® chipset, supporting up to 3 high-performance GPUs.
- **Storage:** 4 × 2.4 TB 12G SAS 10K RPM SFF HDDs; support for up to 16 SAS/SATA/NVMe drives; boot options with dual M.2 SSDs (min. 960 GB each) with RAID 1.
- **RAID Controller:** Hardware RAID supporting RAID 0, 1, 5, 6, 10, 50, 60 with minimum 8 GB Flash Backed Write Cache (FBWC), battery-backed module.
- **Memory:** Support for up to 4 TB DDR5 ECC RDIMMs or 6 TB with Intel® Optane™ PMem modules; minimum installed memory shall be 256 GB (8 × 32 GB).
- **Redundancy Features:** Advanced ECC, memory mirroring, sparing, and failover support.
- **Networking:** 2 × 25 GbE SFP28 ports onboard; 1 × Intel i350 Quad Port 1GbE RJ-45; 1 × dedicated 1Gbps management port.
- **Expansion Slots:** Minimum 3 PCIe Gen 5.0 slots and one (01) modular LAN on Motherboard (mLOM) slot.

- **Management & Diagnostics:** Support for secure out-of-band management, agentless diagnostics, live firmware upgrade, and telemetry; compliance with IPMI v2.0, SNMPv3, Redfish APIs.
- **Security:** Secure Boot, System Lockdown, Platform Firmware Resilience (PFR), Hardware Root of Trust (RoT), Secure Debug & BMC Comms, anti-counterfeit measures.
- **I/O Ports:** 1 × serial port, 2 × USB 3.2 Gen 2 ports, 1 × VGA or MA video port.
- **Cooling & Power:** Hot-swappable redundant fans; hot-plug redundant 1600W 80+ Platinum or Titanium rated power supplies; includes complete rail kit and cable management arms.
- **Operating System Compatibility:** Microsoft Windows Server 2022, Red Hat Enterprise Linux (RHEL) 9.x, SUSE Linux Enterprise Server (SLES) 15 SP4, VMware vSphere 8.x or higher.
- **Form Factor:** Rack-mountable 1U or 2U chassis as approved by the Engineer.

Associated Infrastructure

- A secure 19" standard rack enclosure designed for organizing and housing server and network hardware. It shall include a removable lockable front and rear door, optional side panels with locks, castors or leveling legs, and four heavy-duty vertical mounting rails. Dimensions shall be approximately 1938 mm (H) × 600 mm (W) × 600 mm (D). Final configuration shall be approved by the Engineer.
- A compact 9U wall-mountable rack enclosure for small-scale network equipment installations. It shall include a lockable tinted glass front door, optional lockable side doors, and strong wall-mount support with a load capacity of at least 50 kg. Dimensions shall be approximately 475 mm (H) × 500 mm (D) × 19" (W). To be approved by the Engineer.
- A dedicated Network Video Recorder (NVR) shall be supplied, installed, tested, and commissioned as part of the toll plaza server infrastructure for managing and storing surveillance footage from all cameras (including ANPR, dome, booth, and overview cameras) installed across the toll facility. The NVR shall be capable of recording, managing, and storing high-resolution video surveillance from up to 32 IP cameras simultaneously. It shall support dual-stream compression (H.264 / MJPEG), provide up to 128 Mbps recording throughput, and offer video output via 3 HDMI and 1 VGA ports. It shall feature an embedded Linux OS, a graphical user interface (GUI), motion detection (396 zones), and 64 alarm inputs/outputs for event triggers. The NVR shall support manual, scheduled, and motion-based recording modes, with playback options including smart and time-based search. Storage shall be supported via 4 SATA ports (up to 32 TB total), one (01) eSATA port, and backup via USB or network. Network connectivity shall include 1 × RJ-45 (10/100/1000 Mbps), with support for major protocols (IPv4/6, HTTP, FTP, ONVIF v2.3, etc.). Mobile access shall be available for iOS, Android, and Windows platforms. The system shall support up to 128 user accounts and operate within -10°C to +55°C and 10–90% RH. Power input shall be AC 100–240V, 50/60 Hz. The

brand/model shall be subject to approval by the Engineer 42U Rack assembly with 4 AC cooling fans, perforated removable front door with a lock, one rear door, superior ventilation, min.4 nos. of heavy-duty feet/wheels posts, min. two nos. power strip having min. six outlets each (16 Amp)

- KVM Switch: A 24-port KVM (Keyboard-Video-Mouse) switch enabling centralized control of multiple computers with support for both PS/2 and USB peripherals. Features include hot-swap ability, firmware upgrade via mini-USB, auto-scan interval control, and support for up to 2048 × 1536 resolution. Compatible with various operating systems, including Windows, Linux, macOS, and Sun Microsystems. Operating temperature: 0–50°C; Humidity: 0–80% RH. Certified with FCC, CE, and other international standards. Powered via an external adapter. Brand to be approved by the Engineer.
- Core aggregation Switch: A high-performance Layer 2/3 managed core switch shall be installed in the Toll Plaza Server Room to aggregate network traffic from toll lanes, plaza switches, and the central server infrastructure. The switch shall provide a minimum of 24 or 48 auto-negotiating 10/100/1000 Mbps RJ-45 Ethernet ports along with four high-speed 1G/10G SFP+ uplink ports, each populated with multimode fiber (MMF) modules. It shall offer a minimum switching capacity of 128 Gbps and a forwarding rate of at least 95 million packets per second (Mpps) to ensure efficient data throughput with minimal latency. The switch must support dedicated stacking with a minimum stacking bandwidth of 48 Gbps to allow future scalability and redundancy. Key networking features shall include VLAN segmentation, Access Control Lists (ACLs), Quality of Service (QoS), IGMP snooping, Spanning Tree Protocol (STP), Rapid Spanning Tree Protocol (RSTP), and support for Virtual Router Redundancy Protocol (VRRP). The switch shall include dual hot-swappable power supplies and modular fans for high availability and fault tolerance. Management interfaces shall include console port, web-based GUI, SNMPv3, USB, and Command Line Interface (CLI). The unit shall be fully rack-mountable (19") and installed in a secured 42U network rack enclosure. All equipment shall be CE, FCC, RoHS compliant, and conform to IEEE 802.3 standards.
- Industrial PoE Switches for Field Equipment (Edge Devices): To support the operation of edge devices such as ANPR cameras, PTZ surveillance units, vehicle detection sensors, and other Intelligent Transport System (ITS) components, industrial-grade rugged PoE switches shall be installed in roadside and outdoor equipment enclosures. Each switch shall provide a minimum of 8 × 10/100 Mbps PoE-capable RJ-45 Ethernet ports, of which at least six (06) ports must support Power over Ethernet (PoE) with a combined power budget of no less than 60W. The switch shall include 2 SFP uplink ports, each equipped with multimode fiber (MMF) modules to ensure reliable, high-speed data backhaul to the plaza or server room. The switch must be DIN-rail mountable and designed for operation in harsh environments with an ingress protection rating of at least IP30. It shall function reliably in ambient temperatures ranging from –10°C to +60°C. The device must comply with relevant standards such as IEC 60068-2-6/27/47/64 for vibration and shock, IEC 61000-4-5 for surge protection, and NEMA TS-2 for

ITS applications. Power input shall be compatible with 48V DC industrial power systems. Web-based or CLI management capability is preferred for remote configuration and monitoring, although unmanaged variants may be used in simple deployments where security segmentation and redundancy are handled elsewhere. The installation of these switches shall ensure reliable network connectivity and power delivery to all field-level devices in compliance with the overall Toll Management System design.

- **Server Room UPS 30kVA (60 mins battery backup):** A 30kVA online uninterruptible power supply (UPS) system shall be provided for the server room to ensure continuous and stable power for critical equipment. The UPS shall operate within an input voltage range of 160 – 275V AC, single phase or 3-phase as required, at 50 Hz, and shall deliver a regulated output of 220V $\pm$ 1%, 50 Hz, single phase. It shall be equipped with a central control unit and intelligent power management features. The UPS must include comprehensive protection mechanisms, including lightning and surge protection, blackout management, overvoltage and undervoltage protection, overload prevention, and safeguards against battery undercharge and overcharge. The system shall ensure a minimum of 60 minutes of battery backup at full load and be supplied with all required batteries, cabling, racks, and accessories. The solution shall support real-time monitoring, remote diagnostics, and integration with the toll plaza's power infrastructure, and shall be installed, tested, and commissioned as per the Engineer's direction. All components must comply with relevant IEC, CE, or equivalent international standards.

Additionally, the requirement for server room environment (temperature, humidity, dust control etc.), fire detection and protection system, access control system, security and others shall be met as per the minimum standard specified in Section 7.33 of this Specification or as approved by the Engineer.

7.37.6. Toll Management System (TMS) – System Architecture and ETC Subsystems

The Toll Management System (TMS) shall serve as the centralized, modular, and scalable umbrella platform responsible for the comprehensive management, coordination, and monitoring of toll plaza operations. The TMS shall be based on a distributed client-server architecture and shall enable seamless communication between lane-level equipment, local toll plaza servers, and the central back-office systems.

The TMS shall support both real-time and batch data processing modes to ensure reliable toll collection, monitoring, and reporting under all operating conditions. It shall integrate all subsystems using a secure, high-availability data exchange framework and shall function as the central intelligence unit that interfaces with field devices to handle toll transactions, customer accounts, violation enforcement, and operational reporting.

The TMS shall be developed on a **distributed client-server architecture**, comprising three tiers:

- **Field-Level Tier:** Lane-level devices such as lane controllers, AVC sensors, AVI/ANPR units, RFID readers, barriers, and payment modules.
- **Plaza-Level Tier:** Local Toll Plaza Server(s) for data aggregation, user interface, short-term storage, and device monitoring.
- **Central Back-Office Tier:** Remote data center hosting the host systems, databases, enforcement modules, and integration gateway to the Central Clearing House (CCH).

System Functional Requirements

- Real-time and batch processing modes for all tolling transactions.
- Redundancy and failover for all critical systems (RAID for storage, dual LAN, dual power).
- Secure APIs for data exchange between plaza and central systems (REST/HTTPS/SFTP).
- Configurable toll fare tables, exemption rules, transaction thresholds, and event alarms.
- Web-based centralized monitoring dashboard with multi-role user authentication.
- SLA-driven auto-notification, alerts, and escalation workflows for fault detection and resolution.

The TMS shall incorporate and manage the following four core Electronic Toll Collection (ETC) subsystems as outlined below:

7.37.6.1. Automatic Vehicle Classification (AVC)

The AVC subsystem shall be responsible for detecting, classifying, and validating the vehicle type and configuration for appropriate toll determination. It shall include:

- **Vehicle detection technologies** such as inductive loops, piezoelectric sensors, infrared sensors, and laser scanners are installed overhead or embedded within the lane.
- **Height sensors and axle sensors** capable of determining the vehicle profile, including the number of axles, spacing, and overall height.
- Classification accuracy shall be not less than 98% for all standard vehicle types, including motorcycles, light vehicles, heavy trucks, and articulated vehicles.
- The system shall integrate in real-time with lane controllers and toll transaction modules.
- Equipment shall support high-speed operation (up to 120 km/h) and be designed for all-weather functionality with protection ratings of IP68 or higher.
- System logic shall comply with RHD vehicle classification rules and allow configurable classification categories.

7.37.6.2. Violation Enforcement System (VES)

The VES subsystem shall be implemented to identify and record toll violations, including non-payment, incorrect classification, or misuse of ETC lanes. The system shall comprise:

- High-resolution ANPR (Automatic Number Plate Recognition) cameras, capturing both front and rear license plates.
- Illumination units with infrared and/or white light to ensure night-time visibility and clarity.
- Violation image capture with timestamp, lane ID, toll booth ID, and transaction ID.
- Storage and synchronization with transaction records for post-processing and reporting.
- Capability to interface with enforcement systems and the RHD database for violator identification and notice issuance.
- Audible/visual alarms (optional) for real-time violation alerting to toll operators.

7.37.6.3. Automatic Vehicle Identification (AVI)

The AVI subsystem shall be responsible for accurately identifying vehicles for toll transactions through either tag-based or camera-based methods. The subsystem shall support:

- **RFID-based vehicle tagging system** with long-range (≥ 10 m) readers and passive UHF tags compliant with ISO 18000-6C / EPC Gen2 standards.
- **DSRC-based On-Board Units (OBU)** and Roadside Units (RSU) operating at 5.8 GHz (ISO 14906, CEN DSRC compliant), if applicable.
- **Camera-based video tolling system**, integrated with the ANPR to identify vehicles without tags.
- **Multi-protocol support** to accommodate multiple tag types and tolling technologies across the country.
- Robust **anti-fraud mechanisms** such as tag cloning detection and tamper-proof installation.
- System latency not exceeding 50 milliseconds to support free-flow operation.

7.37.6.4. Transaction Processing System (Back Office Integration)

The transaction processing subsystem shall handle the secure processing, storage, and reconciliation of all toll transactions. This includes:

1. **Lane-Level Transaction Processor**
 - Capture AVC, AVI, ANPR, payment, and operator input.
 - Store transactions locally with time stamps and unique transaction IDs.
 - Reconcile once the uplink is re-established in offline scenarios
2. **Host System**

- Aggregation of all transactions from multiple toll lanes.
 - Management of system parameters, configuration files, and toll rates.
 - Secure log storage and periodic synchronization with the central back office.
- 3. Customer Service Center (CSC)**
- Management of ETC accounts (registration, recharge, and update).
 - Manage RFID/DSRC tag lifecycle, recharges, and balance notifications.
 - Provide web-based and mobile portal for user interaction.
 - Support prepaid, postpaid, and discount plans.
 - Reconciliation of RFID and video-based transactions with account holders.
 - User notification (via SMS/email) for low balance, violations, and payment confirmations.
 - Helpdesk and query resolution services.
- 4. Violation Processing Center**
- Review and validation of violation images and metadata.
 - Matching of license plate images with the vehicle registration database.
 - Generation and dispatch of violation notices and penalty invoices.
- 5. Integration with CCH**
- Real-time secure exchange of transaction and settlement data with Central Clearing House.
 - Compatibility with national tolling protocols and digital signature standards.
 - Support for data auditing, daily settlement reports, and financial reconciliation.

7.37.6.5. System Monitoring and Reporting

A unified monitoring and incident management module shall be integrated and include the following key features:

- Real-time equipment health status: lane controller, barrier, camera, sensor, server.
- Incident/Event log with timestamps, cause codes, and resolution tracking.
- SLA dashboards to track system uptime and availability.
- Automated reports: downtime logs, performance statistics, transaction summaries.
- Alert mechanisms: Email/SMS/pop-up alerts for system faults.
- CRM-like workflow for ticketing, escalation, and resolution tracking.

7.37.6.6. Hybrid Tolling Support

The TMS shall support multiple payment modes and hybrid tolling structures:

- Cash, RFID/DSRC ETC, ANPR-based video tolling
- Daily, return, and monthly passes with expiry tracking

- Special category exemptions (e.g., emergency, government vehicles)
- Discounts for frequent users or fleet accounts
- Integration with QR code/mobile wallet/card-based options (where applicable)

Technical Features:

- Configurable fare matrix for different vehicle classes and toll points.
- Operator override and correction module (with audit logs).
- Offline mode support with sync and validation on reconnection.

7.37.6.7. Security and Compliance

- End-to-end encryption for data in transit and at rest (AES-256, TLS 1.2 or higher).
- Role-based access control (RBAC) with audit trails.
- Authentication via password, OTP, or biometric (optional).
- Database: Industry-standard RDBMS (e.g., PostgreSQL, MySQL, Oracle) with backup/restore.
- All software, firmware, and hardware shall comply with:
 - **ISO 17573-1** (ETC interoperability)
 - **ISO 18000-6C, ISO 14906, EN 15509** (RFID, DSRC)
 - **NIST/OWASP** cybersecurity best practices

These four ETC subsystems shall be designed and integrated by the contractor using proven, standards-compliant technologies. All components shall comply with international protocols (ISO, CEN, IEEE) and shall be interoperable with RHD's existing and future tolling infrastructure.

7.37.7. Testing and Commissioning of ETCS (Electronic Toll Collection System)

The Contractor shall demonstrate full compliance of the entire ETCS (Electronic Toll Collection System) with the Contract requirements through a structured series of tests and inspections covering all critical subsystems, including AVC, VES, AVI, Transaction Processing, and Toll Management System (TMS). The tests shall ensure hardware-software integration, operational readiness, and long-term system performance.

The testing and commissioning process shall include the following categories:

1. FAT (Factory Acceptance Test)
2. PT (Pre-commissioning Test)
3. CT (Commissioning Test)
4. OAT (Operational Acceptance Test)

5. EOWI (End-of-Warranty Inspection)

The Contractor shall provide all equipment, software, materials, and resources necessary to conduct these tests. All costs for conducting the tests, including travel, lodging, and logistical arrangements for Employer representatives, shall be borne by the Contractor.

For each of the tests listed above, the Contractor shall submit a detailed test plan at least 14 days prior to the proposed test date. Each plan shall include:

- Test objectives and methodology
- List of components/devices under test
- Test tools and procedures
- Expected outcomes and pass/fail criteria
- Test report templates

Test milestones shall be included in the Contractor's program schedule. Each test phase shall result in a signed Certificate of Testing upon successful completion.

7.37.7.1. Factory Acceptance Test (FAT)

FAT shall be conducted at the manufacturer's facility before shipment to the site. The FAT shall cover:

- Lane controller units
- AVC equipment (sensors, height detectors)
- ANPR and overview cameras
- RFID readers and/or DSRC RSUs
- Toll booth terminals and printers
- TMS software modules

The Employer or their representative shall attend FAT. The Contractor shall give 4 weeks' advance notice and cover the travel and stay for up to 6 Employer representatives across 2 FAT events.

7.37.7.2. Pre-commissioning Test (PT)

Once installed, the Contractor shall verify proper installation and basic functioning of each component. Tests shall include:

- Electrical and network connections
- Mounting integrity and weatherproofing
- Device health and diagnostic checks

- Loop detector calibration and signal test

7.37.7.3. Commissioning Test (CT)

CT shall involve full subsystem integration and verification of end-to-end toll transaction processing. This includes:

- Synchronization of AVC, AVI, VES with TMS
- Real-time toll calculation and tag/plate matching
- Testing of alarms, notifications, and error recovery
- Communication between lane equipment and the plaza server

7.37.7.4. Operational Acceptance Test (OAT)

The system shall be operated continuously under live or simulated traffic conditions for a minimum period of 15 consecutive days.

- All components must remain fully functional
- Downtime for any component exceeding three (03) cumulative hours shall trigger a full restart of the OAT (unless due to non-Contractor causes such as power failure, telecom outage, or third-party damage)

The OAT shall validate system resilience, redundancy, transaction accuracy, and data reporting.

7.37.7.5. End-of-Warranty Inspection (EOWI)

Conducted at the end of the Defect Liability Period (DLP), this inspection ensures the system is still compliant with all specifications. The Contractor shall:

- Perform diagnostics on each subsystem
- Demonstrate ongoing functionality and system health
- Replace or repair faulty components

The Employer reserves the right to engage an independent auditor during EOWI.

- Tests must include integration with the back office/customer service center
- All logs, event data, and transaction records during tests must be stored and submitted to the Engineer for review
- The Contractor shall ensure all required licenses, warranties, patches, and cybersecurity protections are implemented prior to testing

7.37.4. Measurement

The measurement for the Toll Plaza Electronic Toll Collection System (ETCS) shall encompass the complete range of activities required to deliver a fully functional hybrid tolling solution. This includes the design, supply, installation, integration, configuration, testing, commissioning, operation, and support of the system across both lane-level and plaza-level components. The Contractor shall be responsible for all deliverables necessary to achieve full interoperability, performance compliance, and system certification. Payment shall be made based on the successful completion and acceptance of each component or system, as per the specified units in the Bill of Quantities.

Each toll lane shall be measured on a per-lane basis and shall include all equipment, software, and integration required to implement an operational hybrid tolling lane. This includes the installation and configuration of RFID or DSRC readers, antennas, ANPR cameras, OCR software, inductive loops, axle and height sensors for vehicle classification, smart card and barcode-based semi-automatic fare modules, POS terminals for manual tolling, thermal printers, electromechanical barrier gates, lane controllers with embedded software, and all required control and monitoring peripherals. Additionally, intercom slave units, emergency footswitch alarms, LED-based lane traffic signals, overhead lane status displays, surveillance cameras, and incident detection systems shall be considered part of the lane's measurement. The work shall include all supporting electrical, communication, and networking works necessary for reliable real-time operation, including structured cabling, mounting brackets, protective enclosures, and cable management within each toll lane.

Plaza-level infrastructure shall be measured on a per-plaza basis and shall include the installation and integration of the Toll Management Software (TMS), including licensing, configuration, database setup, and user administration modules. This also includes the supply and commissioning of the toll plaza server, application server, AVC/ANPR processing workstation, rack-mounted Network Video Recorder (NVR), and all related hardware such as racks, displays, operator terminals, and control room surveillance interfaces. The plaza-level measurement also includes UPS systems, KVM switches, edge routers, firewalls, and network switches, all configured and integrated into a secure and redundant architecture. Fiber optic backbone installation, internet connectivity with VPN to the central system, endpoint security software, and other related components are part of the measurement as well. All software and hardware at the plaza level must function as a cohesive system in full compliance with RHD interoperability standards and support real-time synchronization with the national clearing house and central monitoring system.

Subsystem software, including lane control, AVI, ANPR, AVC, TMS core, transaction processing, hybrid payment handling, and system monitoring modules, shall be measured on a functional and operational basis. The software shall be fully installed, tested, and integrated with hardware components, and measurement shall be based on its confirmed ability to process transactions, generate

reports, interface with RHD's central systems, and deliver operational performance in line with the project requirements.

All software procured and implemented under this contract shall be the sole intellectual property of the Roads and Highways Department (RHD). The Contractor shall hand over the complete source code (where applicable), configuration files, compiled binaries, and system documentation to RHD, along with licenses and user rights. The Contractor shall also provide detailed training to RHD's MIS personnel, engineers, and authorized experts to ensure the department can operate, configure, and maintain the software independently. This training shall include system administration, troubleshooting, updates, report generation, user management, and future integration methods.

Testing, commissioning, and training activities shall be measured as a lump sum per toll plaza and shall include Factory Acceptance Testing (FAT), Pre-commissioning Testing (PCT), Commissioning Testing (CT), Operational Acceptance Testing (OAT), and End-of-Warranty Inspection (EOWI). Training shall be delivered to designated staff and shall include hands-on practice, classroom instruction, manuals, SOPs, and troubleshooting guides.

Operation and Maintenance of the ETCS system may be undertaken by a separate contractor. Accordingly, the Contractor shall be responsible only for the maintenance services during the stabilization or Defects Liability Period, including preventive and corrective measures, warranty support, performance tracking, and system updates. All maintenance activities shall be carried out as per the latest RHD Operation and Maintenance Manual for Toll Plazas and ETCS Systems. The Contractor shall ensure full cooperation during the handover of the system to the operations agency and transfer all administrative access credentials, documentation, and knowledge resources in a structured and verifiable manner.

The specification described in this document includes all necessary components, infrastructure, and interfaces required for the construction of a new hybrid ETCS toll plaza. However, these same specifications shall also be applicable for the upgrade, extension, or partial replacement of existing toll plazas, provided that all new components maintain compatibility with the legacy equipment and software. The Contractor shall ensure backward compatibility where required and confirm integration feasibility during the design and implementation phase.

All associated civil, structural, and electrical works related to the ETCS system, such as trenching, ducting, pole installation, island protection, booth electrification, lighting, earthing, and surge protection—shall be measured separately under their respective BOQ items but must be completed and operational for the ETCS system to be considered complete.

Final measurement and payment shall be authorized only after the successful completion of all works, full system demonstration, performance validation, and submission of all documentation, including as-

built drawings, compliance certificates, warranties, license keys, administrative credentials, and training records. Approval by the Engineer is required for the release of payment. Partial or incomplete systems will not be accepted for measurement or payment under any item

7.37.5. Payment

The payment shall be made for design, supply, configuration, installation, and commissioning of the electronic toll collection system based on the number of lanes to be covered and as a complete job on the identified stretch of highway, as per directions of the Engineer. The pay items include items that are not exclusive to ETCS but can be integrated with the ETCS system for hybrid operation. The associated civil and structural works for new Toll Plaza construction, including RCC works (such as Toll Plaza building, canopy, tunnel, and pavement), steel structures (including poles, gantries, and cantilevers), traffic signage, pavement markings, and other related infrastructure shall be covered under the respective pay items described in the relevant sections of the Roads and Highways Department (RHD) Technical Specifications. The following pay items outline the mandatory/alternative/associated components required for implementing ETCS/Hybrid-ETCS, subject to technological advancements, and specific technical requirements that may vary based on evolving needs and project requirements.

Pay Item No.	Description	Unit
	ETCS Toll Hardware and Accessories	
7.37.1	Supply, installation, testing, and commissioning of UHF RFID Reader with minimum 30 meters read range, ISO 18000-6C EPC Class 1 Gen2 compliance, operating at 902–928 MHz with FHSS/Fixed Frequency modes, IP68 rated enclosure, adaptive air interface, support for $\geq 99.5\%$ read reliability, and output via RS232/RS485/Wiegand/Ethernet.	Per Set
7.37.2	Provision and integration of DSRC RSU compliant with ISO 14906/EN 12253, operating at 5.8 GHz, supporting session-based communication with OBUs, AES-128/256 encryption, mutual authentication, bidirectional data exchange, IP65 enclosure, and network interface via Ethernet or RS422.	Per Unit
7.37.3	Supply of vehicle-mounted OBU device compatible with CEN DSRC and RHD TMS, supporting IC Card interface, secure cryptographic key exchange, AES encryption, quick response time (≤ 50 ms), and tamper-resistant casing with windshield mount.	Per Unit
7.37.4	Installation and configuration of lane-level controller with embedded CPU, multi-I/O ports, integrated SSD ≥ 512 GB, real-time control of lane equipment (barrier, cameras, AVC, ANPR), running on secure OS with full TMS compatibility.	Per Lane

Pay Item No.	Description	Unit
7.37.5	Supply and setup of electromechanical toll lane barrier gate with boom arm (anti-collision), opening/closing time ≤ 0.3 s, reflective strip, fail-open feature on power failure, vandal protection, and IP66 rated housing.	Per Unit
7.37.6	Installation of IP-based ANPR camera with OCR engine, resolution ≥ 4 MP, IR illumination ≥ 30 m, WDR ≥ 120 dB, supports Bangla number plates, IP67/IK10 rated, and integrated with TMS and enforcement system.	Per Unit
7.37.7	Supply and installation of 5MP overview bullet camera (CMOS sensor), day/night IR, onboard storage, motion detection, and minimum IP66/IK10 enclosure, with field of view $> 88^\circ$ and ONVIF compliance.	Per Unit
7.37.8	Provision and installation of 5MP fixed dome camera with IR night vision, IK10 vandal-resistant housing, varifocal lens (2.8–12 mm), PoE powered, and full HD video streaming with local storage support.	Per Unit
7.37.9	Installation of dual magnetic loop sensors (presence + exit), embedded in pavement, connected to a multi-channel loop controller, with adjustable sensitivity/frequency, LED indicators, and Level A classification accuracy as per ATCC standards.	Per Lane
7.37.10	Supply and configuration of laser and piezo-based axle sensors with IP68-rated enclosure for axle count and height profiling, integrated with lane controller and compliant with RHD AVC classification logic.	Per Lane
7.37.11	Installation of a 24" full HD LED monitor with an anti-glare panel, 1080p display, integrated with a lane controller for a GUI interface, real-time transaction monitoring, and vehicle classification display.	Per Unit
7.37.12	Supply and installation of 203 dpi direct thermal printer with barcode printing (QR, 1D/2D), auto-cutter, receipt buffer, compatible with Epson driver, and MCBF ≥ 52 million lines.	Per Unit
7.37.13	Provision of passive UHF vehicle tags for Touch and Go ETC system, featuring EPC Gen2 encoding, windshield-mountable design, tamper-proof construction, read range up to 10 meters, anti-cloning security, and full compliance with ISO 18000-6C standards.	Per Unit
7.37.14	Supply and setup of LED-based traffic light with red and green indicators, 200 mm dia, automatic night dimming via photo-sensor, synchronization with barrier gate, visibility > 100 m, IP66 rated.	Per Unit
7.37.15	Installation of OHLS unit with red cross / green arrow LED display, mounted on canopy, IP66-rated, visibility ≥ 300 m, with industrial-grade controller, vandal-resistant, and sunlight legible.	Per Unit

Pay Item No.	Description	Unit
7.37.16	Supply and installation of 600 × 600 dpi laser printer with auto-duplex, 150-sheet output tray, 128 MB memory, 26 ppm speed, network (10/100 Ethernet) and USB connectivity, and compatibility with A4/A5/B5/Legal media.	Per Unit
7.37.17	Provision and installation of outdoor IP66-rated cabinet with anti-vandal structure, 19" rack rails, alarm module, temperature/humidity sensors, internal power strip, cable glands, earthing bar, and lockable doors.	Per Unit
7.37.18	Supply, installation, and commissioning of Intercom Slave Unit at each toll booth for two-way hands-free communication with the control room. Includes microphone, speaker, call button, indicator LED, power connection (PoE or DC), and weatherproof housing. Mounting, wiring, labeling, and integration with the master system are included.	Per Unit
7.37.19	Intercom Master Communication Unit – Control Room (Up to 10 Channels): Supply, installation, and commissioning of Intercom Master Unit in the control room capable of managing up to 10 intercom slave units. Includes channel selector buttons, speaker, microphone, LCD display, amplifier, and broadcast capability. All accessories, cabling, and configuration included. To be used for plazas with less than or equal to 8 lanes.	Per Unit
7.37.20	Intercom Master Communication Unit – Control Room (Up to 20 Channels): Supply, installation, and commissioning of Intercom Master Unit in the control room capable of managing up to 20 intercom slave units. To be used for plazas with more than eight (08) lanes. Includes channel selector buttons, speaker, microphone, LCD display, amplifier, and broadcast capability. All accessories, cabling, and configuration included.	Per Unit
7.37.21	Supply, installation, testing, and commissioning of an emergency footswitch alarm system in each toll booth, including a floor-mounted steel footswitch connected to the lane controller and an external high-decibel siren (≥ 112 dB) mounted on the booth. Includes all cabling, terminations, mounting accessories, integration with the Toll Management System, and final configuration as approved by the Engineer.	Per Booth
7.37.22	Supply, installation, testing, and commissioning of a hazard warning beacon on each toll booth island. Includes LED amber flashing beacon with weatherproof enclosure (IP65), power connection, cabling, mounting bracket, and integration with toll lane control system. Configurable flash frequency and manual/auto operation are supported. Final placement and activation logic to be approved by the Engineer.	Per Unit

Pay Item No.	Description	Unit
	ETCS Toll Server & Network Accessories	
7.37.23	Toll Plaza Server (Administration Computer System with OS): Supply, installation, configuration, and commissioning of enterprise-grade rack-mounted toll plaza server with dual Intel® Xeon® Scalable Processors (min. 2.6 GHz, 24 cores each, 36 MB L3 cache), 256 GB DDR5 ECC RAM (expandable to 4 TB), 4 × 2.4 TB 12G SAS 10K RPM HDDs, dual 960 GB M.2 SSDs (RAID 1 boot), and hardware RAID controller supporting RAID 0/1/5/6/10/50/60 with 8 GB FBWC. Includes 2 × 25 GbE SFP28, 1 × Intel i350 Quad Port 1GbE, and 1 × 1Gbps management port. Expansion via 3 × PCIe Gen 5.0 and mLOM slot. Equipped with secure remote management, diagnostics, platform firmware resilience, and redundant power supplies (1600W 80+ Platinum/Titanium). Includes 21.5" LED monitor, USB keyboard/mouse, and supports Windows Server 2022, RHEL 9.x, SLES 15 SP4, VMware vSphere 8.x+. 1U/2U rack-mountable chassis with rail kit and cable management.	Per Set
7.37.24	42U Rack Enclosure with Cooling & Power Accessories: Supply, installation, and configuration of a 42U standard 19" server rack enclosure with lockable front and rear doors, ventilation panels, 4 AC cooling fans, four (04) heavy-duty feet or castors, and at least two (02) power strips (minimum 6 × 16A outlets each). Dimensions approx. 1938 mm (H) × 600 mm (W) × 600 mm (D). Includes cable management accessories.	Per Set
7.37.25	9U Wall-Mount Network Rack Enclosure: Supply and installation of a compact 9U wall-mounted rack enclosure with lockable glass front door, optional lockable side panels, and 19" mounting rails. Minimum load capacity 50 kg, size approx. 475 mm (H) × 500 mm (D) × 19" (W).	Per Set
7.37.26	24-Port KVM Switch with Accessories: Supply and installation of 24-port KVM switch with PS/2 and USB compatibility, 1U rack-mount design, auto-scan support, resolution up to 2048 × 1536, hot-swappable operation. Includes 24 KVM cables and an external power supply.	Per Unit
7.37.27	Supply, installation, testing, and commissioning of a rack-mountable Layer 2/3 managed core switch with a minimum of 24 or 48 × 10/100/1000 Mbps RJ-45 ports and 4 × 1G/10G SFP+ uplinks (MMF modules included). Switch shall support VLAN, QoS, IGMP, STP/RSTP, VRRP, with a minimum 128 Gbps switching capacity, 95 Mpps forwarding rate, 48 Gbps stacking, and dual redundant power supplies. Includes mounting, cabling, labeling,	Per Unit

Pay Item No.	Description	Unit
	configuration, and integration with the Toll Management System. Make/model as approved by the Engineer.	
7.37.28	Supply, installation, testing, and commissioning of an industrial-grade, DIN-rail mountable PoE switch with a minimum of 8 × 10/100 Mbps ports (at least 6 PoE, 60W power budget) and 2 × SFP uplinks (MMF modules included). IP30 rated, operating –10°C to +60°C, compliant with IEC 60068 and NEMA TS-2. Includes fiber uplink, power connections, field mounting, cabling, and integration. Make/model to be approved by the Engineer.	Per Unit
7.37.29	Network Video Recorder (NVR): Supply, installation, testing, and commissioning of a 32-channel NVR supporting up to 32 TB storage, 4 SATA ports, dual-stream (H.264/MJPEG), motion detection, HDMI/VGA outputs, and remote access. Includes embedded Linux OS and GUI.	Per Unit
7.37.30	Server Room UPS (30 kVA, 60 mins backup): Supply, installation, and commissioning of 30 kVA online UPS with intelligent power management, real-time diagnostics, and minimum 60-minute full load backup. Includes batteries, cabling, racks, and IEC/CE-certified accessories.	Per Unit
7.37.31	Network Edge Router (e.g., Mikrotik or Equivalent): Supply, installation, and configuration of an industrial-grade edge router for the toll plaza network gateway. Minimum specifications include a quad-core CPU, 1 GB RAM, at least 5 × Gigabit RJ-45 ports, 1 × SFP port, and support for OSPF, BGP, IPsec, and OpenVPN. Includes load balancing, firewall, NAT, VLAN, QoS, and web-based and CLI management interfaces. Rack-mountable with secure power supply.	Per Unit
7.37.32	Layer 2/3 Managed PoE Network Switch (24-port): Installation of a 24-port Gigabit Layer 2/3 managed network switch with 4 × SFP uplink ports and integrated PoE (Power over Ethernet) functionality. Supports VLAN, STP/RSTP, ACL, IGMP Snooping, LACP, DHCP snooping, and remote management via SNMP, HTTPS, Telnet, and SSH. Must comply with IEEE 802.3af/at, CE, and FCC standards.	Per Unit
7.37.33	Next Generation Firewall (NGFW): Supply and configuration of an enterprise-grade hardware firewall (e.g., Cisco Firepower FPR1120-NGFW-K9 or equivalent) with ≥1.5 Gbps stateful throughput and ≥900 Mbps IPS throughput. Supports advanced security features including Intrusion Prevention System (IPS), URL filtering, application control, antivirus, and anti-bot protection. Capable of	Per Unit

Pay Item No.	Description	Unit
	managing $\geq 250,000$ concurrent sessions, VLAN segmentation, and site-to-site/client VPNs. Includes web GUI, CLI access, and centralized management (e.g., via FMC). Must comply with CE, FCC, and Common Criteria EAL4+ standards.	
7.37.34	Fiber Optic Backbone for Toll Plaza: Supply and laying of 24-core underground armored fiber optic cable, including trenching, ducting, jointing, splicing, termination, and installation of ODFs and LIUs. Cable shall be Single Mode OS2, ITU-T G.652D, protected by GI casing at road crossings, and laid at a minimum depth of 0.9 meters. Includes SC/APC connectors and patch panels in rack-mount LIUs. Must comply with IEC 60794 and RoHS standards.	Lump sum
7.37.35	Internet Link and VPN Connectivity: Provision of a dedicated broadband internet connection with secure VPN tunneling (IPSec or SSL), static public IP address, and minimum 99% uptime SLA. The service must support at least 20 Mbps symmetric bandwidth, include optional 4G LTE failover, and ensure MTTR ≤ 4 hours. The setup shall be compatible with the Toll Management System and conform to ISO 27001 standards and applicable ISP licensing regulations.	Per connection
7.37.36	ANPR & AVC Server PC and Monitor: Supply, installation, and configuration of high-performance workstation for ANPR and AVC data processing, including 13th Gen Intel Core i5 processor, 16GB DDR5 RAM, 2TB SSD, 8GB dedicated graphics card, 21.5" FHD monitor, customized industrial grade keyboard, and mouse, fully integrated with the Toll Management System.	Per Unit
7.37.37	Endpoint Security, Antivirus and VPN Clients: Supply and activation of licensed antivirus software and secure VPN client for lane PCs and workstations, providing real-time protection, firewall, malware shield, and encrypted communication in compliance with ETCS security protocols.	Per Unit
7.37.38	Supply, installation, and commissioning of TMS workstation for use by toll system administrators and supervisors. Includes Intel Core i5 processor (2.4 GHz, four (04) cores, 8 MB cache), minimum 4 GB RAM, 300 GB storage, integrated NIC, RJ-45 port, USB ports (1 $\times$ USB 3.0, 3 $\times$ USB 2.0), 17.37" LED monitor, USB keyboard and mouse, and licensed antivirus software. Fully installed and configured as per the Engineer's approval.	Per Set
7.37.39	Supply, installation, and commissioning of a 65" 4K UHD professional-grade LED display for 24 $\times$ 7 CCTV monitoring. Features include 3840 $\times$ 2160 resolution, ≥ 500 cd/m ² brightness, 178° wide viewing angle, HDR support, anti-glare panel, minimum 60,000-hour lifespan, and multi-format inputs (HDMI, DisplayPort,	Per Unit

Pay Item No.	Description	Unit
	USB-C, VGA, DVI). Includes wall mount, cabling, and system integration. Model subject to the Engineer's approval.	
	ETCS software and sub-systems	
7.37.40	Supply, installation, licensing, configuration, testing, and commissioning of centralized, modular Toll Management Software (TMS) with real-time integration of lane-level equipment, plaza servers, and back-office, including user licenses, customization, training for toll operators and engineers, and a minimum of 3 years of post-installation support and updates.	Per Unit
7.37.41	Supply, installation, testing, and commissioning of RFID-based Electronic Toll Collection System , including UHF RFID readers, directional antennas, passive RFID tags, industrial-grade cabling, protective enclosures, mounting structures, and full software integration with the TMS and lane controller for automatic vehicle identification.	Per Unit
7.37.42	Installation and configuration of the DSRC subsystem software , including RSU-OBU communication protocols, transaction handler modules, CEN DSRC/ISO 14906 stack implementation, and full integration with lane-level controllers and TMS for real-time vehicle authentication and tolling.	Per Unit
7.37.43	Supply and integration of ANPR and AVC subsystem software , including OCR engine for number plate recognition, classification logic for vehicle profile determination, interface with sensors (loop, axle, height), and integration with TMS for transaction tagging, violation enforcement, and audit.	Per Unit
7.37.44	Installation, configuration, and integration of lane-level controller subsystem software enabling secure and real-time coordination of lane equipment (barrier, AVC, ANPR, RFID, payment devices), embedded transaction logic, event logging, local data caching, and seamless synchronization with the TMS.	Per Unit
7.37.36	Supply and integration of booth surveillance system software to support live video feed, recording schedules, event tagging, and centralized storage integration via NVR; includes operator interface for control room viewing, footage retrieval, and alert response	Per Unit
7.37.45	Installation and configuration of incident detection software for real-time monitoring of lane activity using analytics or sensor input; detects anomalies such as reverse driving, overspeed, vehicle overhang, or prolonged stoppage, and generates real-time alerts linked to the TMS.	Per Unit

Pay Item No.	Description	Unit
7.37.46	Supply and configuration of vehicle counting and classification software integrating loop detector inputs with AVC sensor data to generate accurate per-vehicle classification records, provide real-time inputs to the lane controller, and enable vehicle flow analytics and reporting via the TMS.	Per Unit
7.37.47	Installation, Testing & and Commissioning of the Entire ETCS System	Lump Sum
7.37.48	Operation and Maintenance of ETCS, including x-year(s) performance monitoring and spare parts	Per Year
	Toll lane Appurtenant	
7.37.49	Toll Booth including air conditioning, lighting, fire extinguishers, wiring, and safety provisions	Per Unit
7.37.50	Supply and Installation of Canopy including structural frame, roofing, and lighting provisions	Lump Sum
7.37.51	Construction and Installation of Toll Island, including drainage, electrical, foundation, and safety provisions	Per Unit
7.37.52	Crash Attenuator / Impact Protection System (Toll Island Upstream) Supply, installation, and commissioning of a crash attenuator system or impact protection barrier at the upstream end of each toll island to reduce the severity of vehicle collisions. The system shall include energy-absorbing modules or redirective barriers designed to deflect or absorb impact forces from errant vehicles. Units shall be equipped with retro-reflective panels for high visibility and comply with relevant crash safety standards (e.g., NCHRP 350 or MASH). Includes anchoring, hardware, protective coating, and integration with toll island layout. The final design is to be approved by the Engineer.	Per unit
7.37.53	Toll Attendant Safety Barrier System (Lateral and Booth Front Protection): Supply and installation of fixed safety barriers for toll attendant protection, including reinforced concrete kerbs, steel or composite side rails, approach-end bollards, and protective skirting around booth areas. Barriers shall be designed to channel vehicles accurately through the lane and protect personnel and equipment from errant vehicle encroachment or protruding loads. Includes structural anchoring, alignment with booth design, safety markings, and any required deflection zones. Design and placement to be finalized as per the site layout and the Engineer's approval.	Per unit

Pay Item No.	Description	Unit
7.37.54	Supply, installation, testing, and commissioning of energy-efficient LED lighting system for individual toll lanes, including overhead LED fixtures, weatherproof enclosures, poles or mounting brackets, wiring, junction boxes, and switching controls. The lighting shall provide uniform illumination for toll operations and vehicle passage, be IP65 or higher rated, and comply with applicable roadway illumination standards. Installation shall be as per the direction and approval of the Engineer.	Per unit
7.37.55	Supply, installation, testing, and commissioning of manual toll collection system equipment comprising a secure POS terminal with touchscreen interface, high-speed receipt printer, tamper-resistant cash vault with lockable compartment, and integrated connection to the lane controller and Toll Management System (TMS) for synchronized operation alongside ETCS and semi-automatic toll collection systems.	Per Lane
7.37.56	Supply, installation, testing, and commissioning of a semi-automatic toll collection system comprising a smart card reader, high-speed 2D barcode reader (capable of reading printed and digital passes), and operator terminal integrated with the lane controller for real-time ticket validation and toll transaction processing.	Per Lane
	Electrical Equipment and Wiring	
7.37.57	Installation of LAN with new power cables, setting up power supply infrastructure, installing lighting, DB Box, Circuit breaker, Power supply, communication systems, etc.	Per Unit
7.37.58	Installing Earthing, 120 Feet of boring, 8mm copper wire, and SPD 63KA Surge protector device	Per Unit
7.37.59	Online UPS 10 kVA for toll booths	Per Booth
7.37.60	Online UPS output transmission line to Lane/Counter	Meter
7.37.61	Cabling/Networking/Installation/Commissioning work	Lump Sum
7.37.62	Voltage Stabilizer 40KV (Lane)	Per Booth
	Trainings	
7.37.63	Training of RHD engineers, MIS officials, and technical personnel on system configuration, database management, report generation, software operation (TMS, ANPR, AVC, RFID/DSRC), performance monitoring, and integration procedures; includes supply of training materials, manuals, access credentials, and system handover documentation.	Lump Sum
7.37.64	Training of newly recruited toll booth operators and supervisors on lane-level equipment operation, transaction entry, pass validation, violation handling, basic troubleshooting, and system hygiene protocols; includes practical demonstrations, visual aids, SOP handouts, and attendance certification.	Lump Sum

7.38. Overload Control System

7.38.1. General

The overload control system through Axle Load Control Stations (ALCS) is a critical component of Commercial Vehicle Operations (CVO) within the broader framework of Intelligent Transportation Systems (ITS). The ALCS system plays a vital role in promoting road safety, preserving infrastructure longevity, and enabling the efficient movement of freight. The primary objectives of the ALCS system include enforcement of legal axle and gross weight limits, reduction of premature pavement deterioration, protection of bridges and highway structures, and a decrease in maintenance costs. Additionally, ALCS supports traffic efficiency by reducing bottlenecks at checkpoints, minimizing fuel consumption, and lowering carbon emissions. It enables equitable use of road infrastructure and contributes to more sustainable and compliant freight operations.

ALCS facilities under RHD differ in design, operational context, and management structure. Accordingly, ALCS deployed by RHD are classified into several types, as outlined in Table 2.1 of the *RHD Supervisory Manual for Axle Load Control Station 2024*. The categorization is based on the following distinguishing features:

- Type of Weigh-In-Motion (WIM) system used (High-Speed WIM or Static/Slow-Speed WIM),
- Integration of weigh measurement systems with toll plazas (if any),
- Availability of unloading facilities such as service areas (SA),
- Provision of U-turn facilities in case of overload without unloading,
- The overload handling procedure is followed on-site.

This technical specification is designed explicitly for Type-1 ALCS, which is a standalone ALCS facility (not integrated with any toll plaza), includes a dedicated service area for unloading, and utilizes a combination of High-Speed Weigh-In-Motion (HSWIM) and Static/Slow-Speed Weigh-In-Motion (SSWIM) technologies for precise axle and gross weight enforcement. This type of station is intended to offer comprehensive overload enforcement capabilities with full infrastructure support, including parking, unloading, and maneuvering space. Therefore, this specification provides the technical and operational guidelines for the selection of Weigh-In-Motion (WIM) systems and sites, construction of associated civil structures, supply, installation, calibration, testing, and commissioning of WIM technology, and the establishment of a fully functional ALCS with all required equipment, devices, and passive infrastructure.

Further details of ALCS types, their comparative features, operational procedures, and supervisory protocols are provided in the *RHD Supervisory Manual for Axle Load Control Station 2024*, which shall be read in conjunction with this specification for planning, deployment, and operations.

7.38.2. Requirements for a WIM System

The following specification for the WIM system shall be applied to specify and check the performance and accuracy of any WIM system in its environment set forth by the COST 323 European WIM specification (2002).

7.38.2.1 WIM System Classification

Weigh-In-Motion (WIM) systems are categorized into six accuracy classes, each tailored to specific applications and requirements, as outlined in Table 7.38-1. For the Axle Load Control Station (ALCS) system being developed, the primary objectives are to identify overweight vehicles and enforce compliance with Bangladesh's legal weight limits. Additionally, depending on the ALCS system's design, there may be a need to preselect overweight vehicles before they reach a static/low-speed weighing station or enforcement point. Therefore, the choice of WIM system accuracy class for the ALCS system should be determined based on the intended application and performance requirements specified in Table 7.38-1.

Table 7.38-1: Accuracy classes of WIM systems.

Class	Applications and Requirements
A (5)	Intended for legal use, such as enforcing statutory weight limits and addressing specific regulatory needs. Also serves as a reference for in-service weight verification, particularly when classes B (10), C (15), D+ (20), or D (25) are used for monitoring an entire traffic stream that cannot feasibly be assessed using static weighing methods.
B+ (7)	Suitable for legal enforcement in specific scenarios where Class A standards are not achievable , subject to approval by legal authorities. Effective for initial screening of overweight axles or vehicles, and for serving as a reference in in-service verifications when lower accuracy classes (C, D+, or D) are applied to full traffic populations.
B (10)	To provide accurate knowledge of weights by axles/axle groups/gross weights, for pavement and bridge design, maintenance, or evaluation, such as aggressiveness evaluation, fatigue damage, and lifetime calculations, for preselection of overloaded axles or vehicles , and for vehicle identification based on the loads.
C (15)	Used for comprehensive statistical analyses, including generating load distribution histograms with small class intervals (1–2 tonnes), and accurate classification of vehicles by weight for infrastructure evaluation and fatigue analysis.
D+ (20)	Supports precise vehicle load classification, making it suitable for in-depth fatigue and infrastructure impact studies.
D (25)	Delivers general weight data primarily for statistical evaluations, economic assessments, and broad vehicle categorization based on weight ranges (e.g., in 5-tonne increments).

Note: Additional Classes: E(30), E(35), etc., may apply to Weigh-in-Motion (WIM) systems that do not meet Class D(25) requirements. They are used for evaluating rough systems or setups in less-than-optimal conditions, providing insights into traffic patterns and load distribution.

7.38.2.2. Selection Criteria for WIM Sites

The selection of a WIM site has a great influence on the accuracy, reliability, and durability of any WIM system. The sites are classified according to the road geometry and pavement characteristics. Table 7.38-2 provides the criteria for different classes of WIM sites.

Table 7.38-2: Accuracy classes of WIM sites.

Criteria	Category	I (Excellent)	II (Good)	III (Acceptable)
Rutting (3 m – beam)	Rut depth max (mm)	≤ 4	≤ 7	≤ 10
Deflection (quasi-static) (13t – axle)	Semi-rigid Pavements			
	Mean Deflection (10^{-2} mm)	≤ 15	≤ 20	≤ 30
	Left/Right difference (10^{-2} mm)	± 3	± 5	± 10
	All bitumen Pavements			
	Mean Deflection (10^{-2} mm)	≤ 20	≤ 35	≤ 50
	Left/Right difference (10^{-2} mm)	± 4	± 8	± 12
	Flexible Pavements			
	Mean Deflection (10^{-2} mm)	≤ 30	≤ 50	≤ 75
	Left/Right difference (10^{-2} mm)	± 7	± 10	± 15
Deflection (dynamic) (5t – load)	Semi-rigid Pavements			
	Mean Deflection (10^{-2} mm)	≤ 10	≤ 15	≤ 20
	Left/Right difference (10^{-2} mm)	± 2	± 4	± 7
	All bitumen Pavements			
	Mean Deflection (10^{-2} mm)	≤ 15	≤ 25	≤ 35
	Left/Right difference (10^{-2} mm)	± 3	± 6	± 9
	Flexible Pavements			
	Mean Deflection (10^{-2} mm)	≤ 20	≤ 35	≤ 55
	Left/Right difference (10^{-2} mm)	± 5	± 7	± 10

Evenness	IRI index			
	Index (m/km)	0 – 1.3	1.3 – 2.6	2.6 – 4.0

Notes:

- The rutting and deflection values apply to temperatures $\leq 20^{\circ}\text{C}$ under suitable drainage conditions.
- (1) APL: A device developed in France for measuring the longitudinal profile using single-wheel trailers at 72 km/h, towed by a car.
- (*) The rating quantifies logarithmic energy dissipation across different wavelength ranges:
 - SW = Small Wavelengths (0.7–2.8 m)
 - MW = Medium Wavelengths (2.8–11.3 m)
 - LW = Large Wavelengths (11.3–45.2 m)
 - Scale from 10 (lowest energy, best evenness) to 1 (highest energy, worst pavement surface).

Table 7.38-3 indicates the recommended choice of site depending on the required level of accuracy.

Table 7.38-3: Selection of WIM as per required accuracy and site condition.

Accuracy	Site I (Excellent)	Site II (Good)	Site III (Acceptable)
Class A (5)	+	-	-
Class B+ (7)	+	-	-
Class B (10)	+	+	-
Class C (15)	(+)	+	+
Class D+ (20)	(+)	(+)	+
Class D (25)	(+)	(+)	+

Legend:

- “-” means insufficient
- “+” means sufficient
- “(+)” means sufficient but not necessary

Road Geometry Requirements

It is strongly recommended that the road section between 50 m upstream and 25 m downstream of the system meets the following geometrical characteristics:

- Longitudinal slope $< 1\%$ (class I site) or $< 2\%$ (other site classes), depending on the site class 5.2.2, and as far as possible, should remain constant.
- Transverse slope $< 3\%$.
- Radius of curvature > 1000 m (but a straight road is preferable).
- WIM systems should be installed away from areas where vehicles experience acceleration or deceleration, such as near traffic lights, toll stations, etc., to ensure uniform vehicle speeds. It

is also advisable to avoid locations where drivers frequently change gears, such as near slip roads.

- Areas where the number of lanes changes should also be avoided, as this may lead to vehicles changing lanes at the WIM site.

Pavement Characteristics Requirements

Pavement characteristics have a significant effect on the signals captured by WIM (Weigh-In-Motion) sensors due to the dynamic forces generated from the interaction between the vehicle and the pavement. Measurement accuracy is not only influenced by longitudinal unevenness but also by surface deterioration, including rutting and deformation. Additionally, cracks in the pavement can compromise the durability or performance of the sensors. Pavement deflection and transverse unevenness may further impact both the reliability and lifespan of WIM systems.

The pavement should meet the following criteria:

- No hard spots in the underlying courses or beneath the wearing course (e.g., toll slabs, service tunnels, etc.).
- Thickness of bonded layers greater than 10 cm.
- Strong mechanical bonding between layers, particularly for bituminous concrete on granular materials stabilized with hydraulic binders. Sensors must be placed in homogeneous layers, not in a joint.
- The surface must be free of deterioration in the sensor installation area.
- Pavement should be uniform across each traffic lane, ensuring that joints of coated materials do not interfere with the sensor installation.
- The pavement classification criteria for different WIM site classes are given in Table 7.5-2, and they should be checked at least 200 m upstream and 50 m downstream of the WIM system.

7.38.2.3. Accuracy or tolerances of WIMs

The widths of the accuracy classes or tolerances have been defined as shown in Table 7.38-4. Four key criteria (gross weight, group of axles, single axles, and axle of a group) are taken into account, depending on the system's requirements. These classes are determined based on the confidence intervals of relative errors concerning static loads or weights. In certain cases, they may also be defined in relation to an established reference standard.

Table 7.38-4: Width of accuracy classes with respect to weight (confidence intervals in %)

Criteria (Type of Measurement)	Domain of Use	Accuracy Class: Confidence interval width (%)						
		A(5)	B+(7)	B(10)	C(15)	D+(20)	D(25)	E

1. Gross weight	Gross weight > 3.5 t	5	7	10	15	20	25	> 25
Axle load:	Axle load > 1 t							
2. Group of axles		7	10	13	18	23	28	> 28
3. Single axle		8	11	15	20	25	30	> 30
4. Axle of a group		10	14	20	25	30	35	> 35
Speed	V > 30 km/h*	2	3	4	6	10	10	> 10
Inter-axle distance		2	3	4	6	10	10	> 10
Total flow		1	1	1	3	5	5	> 5

* For sensors that do not function in static mode or at very low speeds.

This Specification follows the COST 323 European WIM specification (2002) as above for HS-WIM/MS-WIMs.

For, LS-WIM accuracy requirements and testing protocols are followed from the principles as described the International Organization of Legal Metrology (OIML R 134). The equipment proposed must have the necessary OIML R 134 certification, and it shall be provided in the proposal of the Bidder. The relationship between the accuracy classes for single-axle load and, if required, axle-group load and the accuracy classes for vehicle mass is as specified in Table 7.38-5 below.

Table 7.38-5: Relationship between Accuracy Classes between vehicle mass vs single-axle load and axle-group load

Accuracy class single-axle load and axle-group load	0.2	0.5	1	2	5	10
	Accuracy class for vehicle mass					
A (0.2)	✓	✓				
B (0.5)	✓	✓	✓			
C (1)		✓	✓	✓		
D (2)			✓	✓	✓	
E (5)				✓	✓	✓
F (10)						✓

Minimum Required Gross Weight OIML R 134 Accuracy Level: $\pm 2\%$

Corresponding Minimum Required Axle Load or Axle Group Accuracy Class: E ($\pm 5\%$)

These accuracy classes above shall be achieved up to a speed of 7 kmph.

As mentioned above, the scales should also work in static mode, and the accuracy levels in static mode shall be minimum **Class III as defined in OIML R 76**.

Table 7.38-6: Allowable errors for Class III instruments

Load range (as a multiple of e)	Maximum permissible error ($\pm$)
0 to 500 e	± 0.5 e
500 e to 2,000 e	± 1.0 e
Over 2,000 e	± 1.5 e

Note: Load range = weight is on the scale as multiple of e; e = The verification scale interval (e), which is the smallest division the scale can measure (for example, if scale interval is 1 kg, for 2000 kg the maximum permissible error is 1.5 kg or 0.075%, for 5000 kg maximum permissible error is 1.5kg or 003%. So, for higher loads, though the absolute error increases, the permissible percentage error decreases.

7.38.2.4. Environmental Requirements

The following information on climatic conditions in all of the sites shall be considered:

Table 7.38-7: Climate Conditions – Temperature

Temperature	
Average daily range	10°C
Average maximum temperature	35°C
Minimum temperature	11°C
Maximum temperature	45°C
Mean temperature throughout the year	26°C

Table 7.38-8: Climate Conditions – Rainfall

Rainfall:	
Minimum annual	1300 mm
Maximum annual	5500 mm
Average annual	2600 mm
Maximum intensity	300mmlh
Minimum rain days per year	60 days
Maximum rain days per year	150 days

Table 7.38-9: Climate Conditions - Relative Humidity

Relative Humidity:	
Minimum humidity (RH)	50%

Table 7.38-10: Climate Conditions - Average Maximum Humidity

Average maximum humidity (RH)	
Day time	80%

Night time	90%

Wind speed is location-specific, and the parameters in the Bangladesh National Building Code BNBC 2020 shall be considered.

Climatic conditions for equipment installed within air-conditioned rooms are normally governed by the design criteria for the air-conditioning plant, which are:

- Temperature $25 \pm 1^{\circ}\text{C}$
- Relative Humidity $55 \pm 5\%$
- Outdoor ambient temperature 36°C dry bulb
 27°C wet bulb

To cater for any abnormal conditions which may arise, equipment shall be designed to operate in a temperature range from 20°C to 45°C and in a relative humidity of between 40% and 90%.

All outdoor equipment and sensors must have a minimum IP65 ingress protection level, while the sensors and equipment installed on/in the pavement shall have a minimum IP68 level of protection.

All equipment provided under the Contract shall function by the specifications under the environmental conditions stated above. The Bidder shall provide the test certificates performed by accredited laboratories following international standards. Moreover, all of the supplied and installed support structures, such as gantries and poles, shall be designed by taking the environmental conditions above into consideration.

In addition:

- For a basic verification suitable for common applications, it is advisable to compare the manufacturer's specified and guaranteed conditions of use with the detailed requirements outlined in the main document, particularly regarding climatic conditions, traffic factors, and mechanical resistance.
- It is recommended that the site be equipped with both power supply and communication infrastructure, as power installation costs can be significant. Ideally, the location should also feature a static weighing system.
- To ensure safety, adequate space and easy access should be available for installing a roadside cabinet. This cabinet serves to protect the WIM system from adverse weather conditions and potential vandalism.
- WIM systems should not be installed beneath high-voltage power lines to avoid potential interference or safety risks.

- Installing WIM sensors on overpasses should be avoided due to aerodynamic effects, and they should not be placed on bridge approaches with uneven surfaces. Additionally, road sensors should not be installed on bridges or other structures exposed to dynamic forces.

7.38.2.5. On-site System Check and Calibration

Three scenarios must be considered when installing a system:

1. **Single Supplier for Sensors, Electronics, and Installation**
 - No additional checks are required as the supplier's general guarantee suffices.
2. **Manufacturer Supplies Sensors and Electronics, but Installation is Separate**
 - A preliminary acceptance test should be conducted by the client or installer, following contract guidelines and recommendations for mechanical and electrical checking.
3. **Multiple Suppliers for Sensors, Electronics, and Installation**
 - Compatibility between components must be verified before installation, either by the client or through consultation with manufacturers or installers. The procedure outlined in scenario two should then be applied.

In all cases, adherence to the manufacturer's specifications for sensor installation is essential.

Before installing WIM sensors, several quality checks should be performed:

1. **Supplier Quality Assurance** – The supplier must provide a quality assurance procedure detailing the characteristics of the sensors.
2. **Performance Verification** – Each sensor's functionality should be assessed based on the manufacturer's specifications. This can be done systematically by the customer or through sampling using supplier-provided test charts.
3. **Basic Signal Testing** – At a minimum, a simple laboratory test should be conducted to confirm that each sensor generates an appropriate signal.

After installation, a WIM system requires initial calibration, following the manufacturer's guidelines. Compliance with the detailed procedures outlined in this Specification shall be ensured.

If no calibration procedure is provided, or if a system involves multiple suppliers (scenario-3), an appropriate method from Section 7.2 and Appendix III of COST 323 European WIM specification (2002) must be applied.

Ongoing calibration and system checks:

- Regular calibration is required at least once per year (Level 2).
- Monthly checks (Level 1) are preferable when feasible.

Level 1 Check (Basic and Cost-Effective):

- Assessing automatic self-calibration coefficients (if applicable).
- Comparing traffic patterns (e.g., weight and axle load histograms) with reference data from the initial calibration.
- If discrepancies arise, a full accuracy check and possible recalibration will be necessary.

Level 2 Check (Annual In-Service Test):

- A periodic in-service test should be performed once per year.
- If a significant bias is detected, recalibration must be conducted.

7.38.3. Requirements for the ALCS System (Physical Infrastructure and Hardware)

7.38.3.1. Installation Site Requirements

The Contractor is responsible for ensuring that the pavement at the installation sites meets the required standards. Any road rehabilitation necessary for the project must first be approved by the Employer before execution.

Site Selection: The selection of WIM site locations (HS-WIM, MS-WIM, SS-WIM, or Static scale) shall be carried out by the Contractor with support from the Employer. Once the locations are selected, the Employer will review and provide final approval for the chosen sites to ensure they meet the project's requirements.

HS-WIM/MS-WIM Site preparation: The Contractor must ensure that the road surface at all HS-WIM/MS-WIM installation sites is of high quality. All sites must meet the standards for WIM Site Class I (Excellent) to ensure accurate and reliable sensor performance.

To maintain consistency, the Contractor must repave 65 meters before and 25 meters after the HS-WIM/MS-WIM sensors, following the pavement design provided in the Drawings Section of the Bid Documents. During construction, the Technical Specifications of RHD (2024) must be adhered to. Additionally, since the pavement design includes steel reinforcement, the Bidder must take this into account when selecting sensors and making necessary design adjustments before submitting their bid.

SS-WIM/Static scale Site Preparation: In case of the measurement lanes (aprons) at Axle Load Control Stations, which are pre-constructed with reinforced concrete pavement, the design of these aprons shall be provided by the client in the Drawing Section of the Bid Documents for reference.

The Contractor is responsible for installing SS-WIM/Static Scale sensors and platforms within the pavement. The installation costs must cover all necessary pavement demolition and reinstallation (if

required). Since the pavement contains steel reinforcement bars, Bidders must consider the impact on sensor selection, installation methods, and associated costs while preparing their bids.

7.38.3.2. Installation of Supporting Structures and Appurtenances

1. Construction of Gantries and Support Structures

The **Gantry** and **Cantilever** designs shall be provided in the **Drawings Section** of the **Bidding Documentation**. Bidders must submit prices for these structures based on the given designs. If modifications are required to accommodate the Bidder's equipment, these changes must be clearly stated in the bid, with corresponding price adjustments.

The **Contractor** is also responsible for supplying and installing all other necessary **support structures**, such as poles and brackets, for equipment installations at **Axle Load Control Stations**. These structures will support devices like **CCTV cameras, ANPR cameras, RFID readers, Variable Message Signs, and relevant devices**.

2. Requirements for Metal Structures

All **metal structures** used in the project must comply with the following requirements:

- **Welding Standards** – Welding must adhere to the AWS D1.1/D1.1M - Structural Welding Code – Steel standard or standards and norms outlined in the project's design documentation.
- **Protective Coating** – All metal constructions shall be protected with **hot zinc coating** as per Section 7.1.2.5 of this Specification.
- **Transportation** – The transportation of oversized cargo must comply with regulations and be considered during the **detailed design phase**.
- **Installation**– Before transportation, **supporting structures** should be divided into separate parts for ease of installation. At the site, these parts shall be **assembled on the foundation** and connected per **installation/shop drawings**, with joints insulated to prevent corrosion.

3. Foundation Construction and Grounding Requirements

The **Contractor** is responsible for constructing **foundations** for supporting structures and **outdoor equipment cabinets**. While **foundation designs** for **Gantries and Cantilevers** shall be provided in the **Drawings Section** of the **Bidding Documentation**, the Contractor must **verify their suitability** by conducting **geotechnical surveys** at each site.

During **foundation work**, an **outer grounding ring** must be installed. All underground connections should use **approved methods**, such as **pressure-type connectors, brazed connections, or welded**

connections. Inside the **equipment cabinet**, a **main grounding busbar** must be installed for potential equalization. This busbar should be connected to:

- The **protective grounding busbar** of the **main electric switchboard**.
- All HS-WIM/MS-WIM and **Evasion Control site equipment** that requires grounding.
- The **cabinet structure** must be linked to the **outer grounding ring** via the **main grounding busbar**.

The **Contractor** must prepare a **detailed grounding plan**, ensuring that all necessary materials are installed alongside the foundation works. The **cost of concrete foundation work and materials** shall be included in the **scope of delivery**.

4. Installation of Concrete and Reinforced Concrete Structures

Installation of monolithic concrete and reinforced concrete structures shall be carried out following the working drawings of structures, the work implementation plan, and in compliance with the requirements of local standards on metal structure construction and installations.

Foundation requirements include:

- The **installation site** for supporting structures must be prepared according to the **specified dimensions** in the **installation drawings** and design documentation.
- Foundations must adhere to **Bangladesh's state construction norms**.
- The **foundation must be sufficiently massive** to withstand **wind loads**, the **weight of WIM equipment**, and potential future installations.
- The foundation must be constructed using **high-strength concrete**, suitable for the location, with corrosion-resistant properties to ensure durability and **reliable load-bearing capacity**.
- **Structures for equipment installation** should be anchored to the **foundation plate** using **anchor bolts**.
- The **Contractor** must install **safety fences (crash barriers)** around **cabinet and gantry sites** to protect **gantry foundations and electrical installations**.

7.38.3.3. Equipment and Material Supply and Installation

The equipment shall be delivered and installed completely at the place of operation. All hardware modules, components, software, operating systems, etc., which are essential for the perfect functioning of the system, shall be part of the supply and installation. A complete set of the equipment and materials of an Axle Load Control Station System should be delivered in a single delivery, not in multiple lots.

The supplied units, main and auxiliary equipment, as well as materials, shall be tested at the manufacturing plant, delivered to the construction site, unloaded, unpacked, tested, and transferred

properly along with a full package of technical documentation to be installed. All equipment and materials shall be new and unused, manufactured using the latest or currently in production model, and shall include the latest advances in design and material development. Identical items of equipment shall be represented by the products of the same manufacturer.

Wherever practicable, materials shall be used that do not support combustion and that do not give off noxious or toxic fumes when heated. Where it is not possible to meet these requirements, materials shall be selected that provide the minimum practicable hazard, and care shall be taken to minimize the spread and the effects of fire.

All material requirements given in the specifications shall be considered as minimum requirements

Transportation of the main and auxiliary equipment to the site, and its storage before starting installation works shall be carried out by the Contractor. The specified stages shall be implemented strictly following the equipment and materials manufacturers' instructions.

The Contractor shall prepare all installation work (suggested installation places and places for connection to existing systems). The Contractor shall understand that the work described herein shall be complete in every detail, even though every item involved is not specifically mentioned. The Contractor shall make the installation works so that normal traffic on the roads is not unduly disturbed.

The equipment and associated works shall be designed, manufactured, tested, and approved to operate under the requested ambient conditions. The equipment shall be designed to operate reliably across all operating conditions specified in this document in section 7.38.2.4, and it shall achieve its expected useful life while operating in these conditions.

Workmanship shall be of the highest standard, and work shall only be carried out by personnel skilled in the appropriate trade. During the progress of the installation works, all openings on equipment, open ends of pipes, conduits, ducts, cable ends, etc., shall be suitably capped to prevent the ingress of any foreign matter.

All mechanical and electrical parts shall be adequately guarded to ensure the safety of anyone in the vicinity. In areas accessible to the public, the equipment shall be completely closed. Such enclosures shall be strongly made to resist intentional damage and shall have smooth exteriors, free from avoidable irregularities and crevices where dust and damp might lodge. Covers and doors shall have locks or catches that require special keys to open them. They shall not be opened by familiar articles such as screwdrivers, knife blades, square keys, hex keys, etc., or other keys having familiar and easily identified manufactured shapes. Similar enclosures for equipment in the same system shall use identical locks. Two keys shall be provided for each lock, with a minimum of four keys for each type of lock.

The Contractor shall clean all sites and premises used for installation and repair all damages, as well as remove all debris, following local regulations.

7.38.3.4. Equipment wiring and cabling works

The Axle Load Control Stations will be handed over to the Contractor with the underground ducts already constructed. The layout design of the underground ducts shall be given in the Contract Drawings. Also, the layout of the equipment on the ALCS Station shall be given in the Drawing section. It shall be noted that the exact location of the equipment shall be designed by the Contractor to meet the requirements in this document.

When multi-core or multi-pair cables are site-terminated into equipment, the cables shall be properly glanced off, the armoring, if any, properly earthed, and the cable sheath carefully stripped back. Each core shall be identified by cable markers agreeing with the number on the terminal and drawings, and sufficient slack shall be left in the form of a loop-back to leave enough spare cable to re-make a broken end into the terminal at a later date.

Particular attention shall be paid to the neatness and lining up of equipment, cable, conduit, and/or pipe runs as appropriate. Co-operation shall be given to all other Contractors to ensure that the equipment is neatly arranged and fixed.

All electrical assembly work and wiring shall be carried out in a workman-like manner. All wiring within units shall be neatly loomed and secured with insulated cable clips or shall be run in plastic slotted trunking with capping, except where point-to-point wiring technique is employed.

Generally, the preference is for crimped lug connections for power cables and 'wrapped' connections of an approved type on only the correct tools and equipment for crimping, where appropriate test pieces will be requested. Where soldering of components is carried out, it shall be in such a manner as to prevent damage to either the component or the insulation of the wiring. Only resin-cored solder shall be used, and the use of additional flux will not be permitted.

Solder termination of power cables shall not be used.

7.38.3.5. Fiber Optic Cable and Power Cable Installation

The contractor shall install underground fiber optic cable and the electrical power cable between the ALCS and WIM Stations. Via this fiber optic cable, HS-WIM/MS-WIM data will be transmitted to the Axle Load Control Station, and power will be supplied through the electrical power cable.

The fiber optic communication infrastructure and electrical power distribution shall be installed as shown in the following excavation profile, at a depth of 90 cm generally along the highway. Direct

buried type micro ducts, which are suitable for the air-blown fiber installation method, shall be placed for the fiber optic communication infrastructure as well as the electrical power cable. For bridge crossings, microducts shall pass through wider stainless-steel pipes.

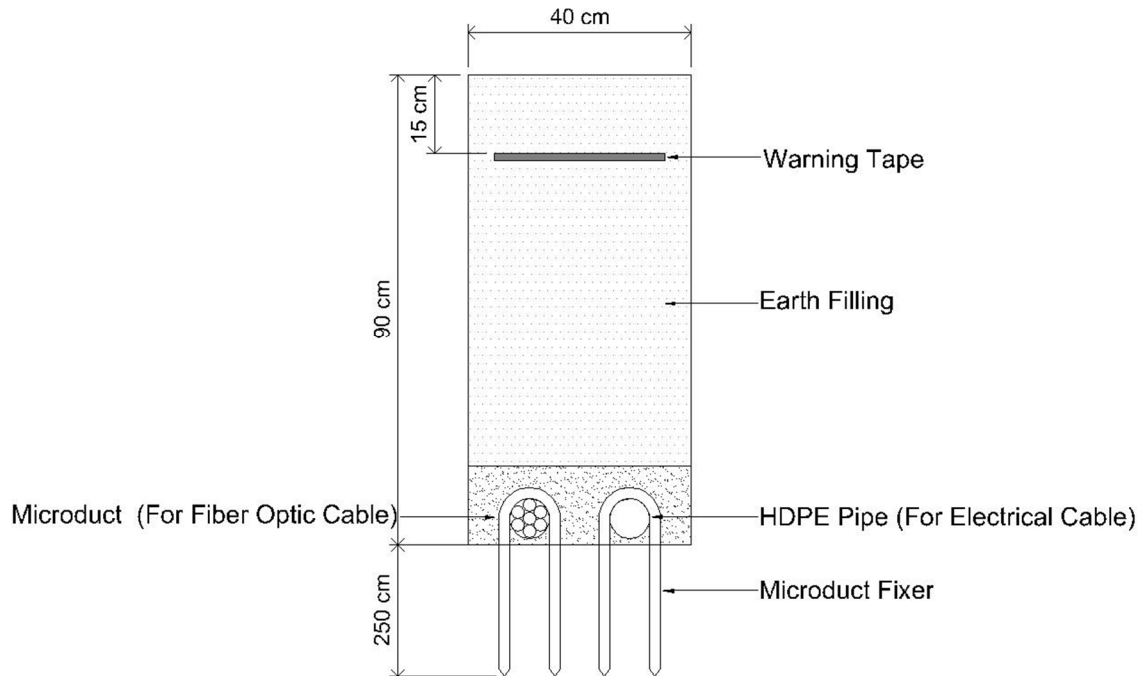


Figure 7.38-1: Cross-section of fibre Optic Installation

Sand Fill: refers to natural (stream) or stone crusher bypass material, or terracing material, or materials with 0-5 mm grain diameter supplied from a ballast quarry.

Earth Fill: refers to material obtained from excavations and having a grain diameter of no larger than 38 mm. The filling materials shall not contain any large stones, rocks, etc.

Small-type prefabricated manholes shall be used at 1 km intervals to enable the installation of micro ducts or Fiber optic and Electrical power cable splices along the route. At the HS-WIM/MS-WIM locations, a large type of manhole shall be installed. Manholes made of polyethylene (PE) or reinforced concrete can be used. Manholes shall be of a suitable type for use in the telecommunication infrastructure and electrical power distribution system. Manholes shall have covers that prevent leakage of surface water into the manholes.

The warning tape must be made of a durable plastic material that is resistant to decomposition and environmental conditions and has a physical life of a minimum of 25 years. The following expression shall be written on the warning tape: “WARNING! F/O, CABLE - RHD.”

- Length: 500 m
- Color: Yellow/ Black

- Type Size: 10 cm.
- Tape Width: 20 cm.

Micro duct fixers should be of suitable size, and diameters shall be installed at every 100 m interval to prevent loosening of the micro ducts, and they should penetrate 25 cm of soil.

The inner and outer surfaces of the microducts shall be smooth and flat. The outer surface of the micro duct shall be of high-molecular feature; it shall be available in different colors with additives and be durable against physical conditions. The microducts installed between HS-WIM/MS-WIM and ALCS shall have a minimum of 2 tubes.

Microducts shall have the following characteristics:

Outer Sheath: Sheath made of thermoplastic, protecting fiber cables against external impacts.

Outer Sheath Stripping: Outer sheath can be easily stripped and cleaned without requiring products such as purifying agents, etc., and inner conduits and/ or Fibers can be uncovered for splicing, etc.

Fiber optic cables shall be single-mode type and they shall have a minimum of 12 cores. fiber optic cable shall be terminated on the Fiber optic patch panel via pigtail cable. Termination and splicing shall be of the "fusion splice" type.

Following termination, all the connectors (prepared for optical purposes) shall be cleaned by using isopropyl alcohol and then immediately sealed with their cover for their protection against dusting, etc. Each fiber shall be tested, and the end-to-end attenuation level shall be measured by using OTDR.

For Electrical Power connection from ALCS to HS-WIM/MS-WIM multicore low voltage cable, NYY, PVC sheathed, non-armored, termite-proof shall be used. The cable should be made and tested according to VDE 0472/6065 and VDE 0472/3.69 for this type of installation, rated voltage being 600/1000V. Also, the cable should be a flame-retardant cable.

7.38.3.6. Grounding and Lightning Protection

Grounding rings shall be installed using flat or round steel, in compliance with applicable norms and rules for the safe operation of electrical equipment. Within the buildings, newly installed equipment shall be grounded by connecting it to new or existing grounding systems. If necessary, additional grounding busbars shall be installed. The type of grounding and power network connection at the server sites in ALCS, MAIN CONTROL CENTER, and WIMs shall be checked on-site.

At the construction site, the site grounding type and network connection shall be clarified by the Contractor.

Lightning protection devices shall be incorporated, at a minimum, on the main power supply to each individual item of equipment and at each termination point of voice and data communication links. Particular attention shall be given to ensuring that such protection remains effective when bypass or interlock facilities are operated.

Where lightning protection involves components likely to require replacement after a strike or multiple strikes, such components shall be positioned conveniently within the enclosure to allow easy replacement without removing any other module or assembly.

Devices that change color to indicate their condition shall be installed in a manner that ensures visibility once access to the appropriate enclosure has been gained.

As far as practicable, effective screening and separation of all light current conductors from power cables, bonding cabling, fluid-carrying pipes, and similar installations shall be arranged to reduce the effects of lightning. In addition, suitable surge suppression or isolation devices shall be provided.

All equipment supplied under the Contract shall either remain fully operational or be capable of being restored to a fully operational condition through the replacement of a minimum number of protective components after a lightning strike at any point within or adjacent to the Site.

The maximum earth loop resistance from any point in the installation, including the earthing led to the earth electrode, shall be less than 5 ohms. Leads must be efficiently bonded to all metalwork other than current-carrying parts to ensure that the specified resistance level is not exceeded.

An earth tester shall be provided, the installation shall be tested in the presence of the authorized representative of the Engineer/Employer, and the earth test report shall be submitted to the Engineer for approval.

Earthing/grounding shall be carried out in accordance with the provided design drawings and specifications. Separate earthing shall be used for equipment and the electrical distribution system.

At the time of bid submission, the means proposed for preventing damage by lightning, whether by direct strike, induced effects, or charging, shall be clearly described.

7.38.3.7. Connection to Electrical Network and Electrical Installation inside Stations

The power connections between the transformer and the buildings and the internal power distribution cables in the buildings shall be installed. The power connection diagram shall be shown in the Drawings Section of the Bid Document for the information of the Bidder.

However, the Bidder shall supply and install power cabling for the following:

- HT Cable between the transformer station and the electrical network grid with an average distance of 80m.
- Between the power distribution board in the Control Building and all of the equipment at the Axle Load Control Stations
- Between the Axle Load Control Station and the HS-WIM/MS-WIM Site.

For connection between the transformer station and the electrical network grid, the bidder shall use Multicore HT (11KV) cable suitable for continuous permissible service voltage of 7000/12000 volts and indoor, outdoor, and underground use. The cable shall be with plain annealed copper conductor, PVC insulated, field limiting conducting layers over each conductor and each core insulation, concentric shields of copper over individual cores, three cores laid up, PVC bedded, flat wire armoring with helical steel taping, and PVC sheathed. Bidder shall also be responsible for laying the required size of PVC pipe by cutting a 45.70cm width x 91.40 cm depth trench, mending well the damages by earth refilling with proper compaction providing 50 mm thick compacted premix bituminous carpeting over one layer of 1st class flat brick soling and 75 mm thick compacted water bound macadam of khoa of brick.

For the connection between the Axle Load Control Station and the HS-WIM/MS-WIM site, an electrical power cable shall be laid through the micro duct, and a separate pipe shall be used for the fiber optic cable and the electrical power cable. The works will be done as per design drawings and as specified in section 7.38.3.5.

Supplies made available at the control building and the weighing area will be nominally at:

- 240 Volt, single phase, 2 wire 50 Hz or,
- 415 Volt, three phases, 4 wire 50 Hz

Actual voltages may vary by $\pm 15\%$ and frequencies by $\pm 4\%$ from the stated figures. Supplies made available at various locations will not necessarily be synchronized in frequency or from the same source.

All equipment and systems shall be capable of withstanding randomly phased transient over-voltages on the power supply without damage and without the performance being affected. These transients may be either common mode or series mode up to the limits shown in Table 7.38-11 below. (Peak amplitudes are expressed as percentages of the supply r.m.s. and the transients may be assumed to be half sine waves.)

Table 7.38-11: Allowable Over-Voltage Transients (Common and Series Mode) Relative to Supply RMS

Over-Voltage Amplitude (% of Supply r.m.s.)	Duration (Milliseconds)

50%	50
100%	10
200%	1
300%	0.02
500%	0.005

Line filters and fast-acting stabilizers shall be provided as necessary to ensure that all equipment and systems installed under the Contract shall perform properly when operating from any supply source and subjected to transients within the limits defined above. These filters and stabilizers shall be provided and installed by the Contractor, and their cost shall be deemed to be included in the Bid.

7.38.3.8. Communication Network

The connection between the Axle Load Control Stations and the Axle Load Main Control Centre in Dhaka shall be provided by using leased lines/data connection services provided by the National Telecommunication Transmission Network (NTTN) operators. The Bidder shall include the cost of connection to such networks for each station and the Main Control Center. Also, during the initial period of operation, the monthly subscription fee shall be included in the operation costs proposed by the Bidder.

The minimum connection speed to each ALCS Station shall be 100Mbps, and the Main Control Center shall be connected at a speed of 2Gbps minimum. The connection between the Main Control Center and ALCSs should be secured, available, and reliable. Redundant and security protocols such as VPN, VPLS, MPLS, BGP, IGP, IPSEC, and L2TP may be considered as minimum requirements for security. Network-level redundancy needs to be ensured by the NTTN service provider to minimize packet loss.

In the communication network, security devices, such as a next-generation firewall, will be used for main server security. The firewall can detect and block sophisticated attacks by enforcing security policies at the application level, as well as at the port and protocol level. The communication network will include the Node level and link level redundancy.

Alternatively, wherever applicable (e.g., sufficient budget available for a dedicated optical fiber network or connection to the existing Optical Fiber Communication (OFC) backbone of the Roads and Highways Department), the communication network shall be established through an Optical Fiber Network from ALCSs to the Main Control Center.

7.38.3.9. Cameras

ANPR (Automatic Number Plate Recognition) Camera

The ANPR cameras shall capture overall photographs and images of front number plates from moving vehicles to read automatically vehicle registration plates. The ANPR system shall be operational in all weather conditions, day and night.

ANPR equipment shall be used at the HS-WIM/MS-WIM site locations and all other sub-systems necessary to identify the vehicles.

ANPR cameras used in the whole ALCS system at any location shall:

- be capable of reading correctly at least 95 % of the passing vehicle's number plates;
- alarm on the Operator's screen if the confidence level of the number plate reading of the violating vehicle is less than a user-configurable threshold set in the system;
- use IR-illumination (supplied IR illumination can be internal to the camera or external);
- should be able to recognize the license plates of vehicles from Bangladesh, India, and Myanmar;
- use a high-resolution camera (minimum 4MP);
- use auto-triggered operation;
- have a built-in processor.

The ANPR Camera shall meet the following technical specifications:

- Image Sensor: Minimum 1/2.8" Progressive Scan CMOS.
- Resolution: At least 4 Megapixels.
- Shutter Speed: Fast shutter support (e.g., 1/1000 s to 1/15000 s) for motion capture.
- IR Illumination: Integrated or external IR, with a minimum range of 30 meters.
- Minimum Illumination: 0 lux with IR enabled.
- Lens: Fixed or motorized lens (e.g., 8 mm to 32 mm) suitable for license plate capture.
- Wide Dynamic Range (WDR): Minimum 120 dB to handle headlight glare and shadow.
- Frame Rate: Minimum 25–30 frames per second.
- On-board Processor: Integrated OCR engine for edge-based ANPR processing.
- On-board Storage: Supports microSD card (minimum 128 GB).
- Vehicle Speed Handling: Capable of recognizing number plates at vehicle speeds up to 200 km/h.
- Video Compression: Supports H.265, H.264, and MJPEG.
- Network Protocols: IPv4/IPv6, TCP, UDP, HTTP, HTTPS, FTP, DHCP, DNS, SNMP, RTSP, NTP, SMTP, etc.

- API Support: Must support ONVIF and provide an HTTP API or SDK for integration.
- Power Supply: 12V DC $\pm 10\%$, 24V AC $\pm 10\%$, or Power-over-Ethernet (PoE) (IEEE 802.3 af/at).
- Power Consumption: Maximum 15 Watts.
- Operating Temperature: -40°C to $+60^{\circ}\text{C}$.
- Ingress Protection: IP67 (dustproof and waterproof).
- Impact Protection: IK10 (vandal-resistant).
- Camera Housing: Weatherproof metal enclosure, suitable for outdoor mounting.
- Certifications: Must have CE, FCC, and UL certifications.
- Country of Origin: USA, UK, Japan, or EU countries (or engineer-approved equivalents).

Overview Cameras

The Overview cameras shall be used for taking overview photos of vehicles from the front and the side, showing the entire vehicle/road train. And these photos shall be included in the data set for each vehicle as mentioned above.

The Overview Cameras shall meet the following technical requirements:

- 5 MP, varifocal ' IP Bullet CAMERA (including lens, bracket, housing) of the following technical specification or equivalent
- Image Sensor: 1/2.8" Progressive Scan CMOS, 5 Megapixel (minimum)
Min. Illumination: At least 0.185lux/F1.3(color, 30IRE) or 0.15 lux/F1.2(color, 50IRE),
B/W: 0 Lux with IR
Shutter Speed: At least 1/25 s to 1/15000 s
Wide Dynamic Range: 120 dB or above
Lens Type and Focal Length: Varifocal lens. at least 3 to 7.37 mm in Length.
Focal Length & FOV: horizontal FOV 88° - 36° , vertical FOV: 50° - 23° or above
Aperture: F1.4 maximum
Supplement Light Type: IR
IR Range: minimum 30m
- Max. Resolution: 3072 x 1728 or 2592x1944 or 2560 x 1920
Video Stream: At least two (02) streams, Mainstream: 5 MP (1fps-25/30 fps)
Video Compression: H.265/H.264/MJPEG
- Region of Interest (ROI): off/on
Audio Sampling rate: 8kHz/16kHz/48 kHz
Audio Compression: G.711/ G.726/MP2L2/PCM/MP3/AAC
API: ONVIF
Protocols: IPv4, IPv6, UDP, TCP, HTTP, HTTPS, RTP/RTCP, ICMP, NTP, DNS, DHCP, SMTP, etc.

SNR: >55dB

Day/Night: Day, Night, Auto

- On-Board storage: Micro SD Card

Ethernet Interface: RJ-45 (10/100 Base-T)

Basic Event: Motion Detection, Tamper Detection

Power supply: 12 V DC $\pm 5\%$, 24 VAC $\pm 10\%$ or Power-over-Ethernet, PoE (802.3 at /af)

Power Consumption: maximum 15 watts

Camera material: Metal

Operating temperature: -43°C to $+50^{\circ}\text{C}$

Protection: IP67, IK 10

Certifications: CE, UL, FCC

Country of origin: USA/UK/Japan/EU or equivalent (subject to the Engineer's approval)

Note: The updated specification for the bullet camera can be found elsewhere in this document. In addition, the contemporary upgradation of the bullet camera shall be maintained to comply with the installed system.

PTZ Camera

PTZ cameras provide a 360-degree view, making them ideal for monitoring.

The Dome Camera shall meet the following technical specifications:

- Camera Type: IP Dome Camera (including lens, dome housing, and mounting accessories)
- Image Sensor: 1/2.8" Progressive Scan CMOS
- Resolution: Minimum 5 MP (2592x1944 or higher)
- Minimum Illumination:
 - Color: ≤ 0.185 lux @ F1.3
 - B/W: 0 lux with IR on
- IR Range: Minimum 30 meters
- Shutter Speed: 1/25 s to 1/15000 s or better
- Lens Type: Varifocal lens, at least 2.8 mm to 12 mm
- Aperture: F1.4 or better
- Field of View:
 - Horizontal FOV: 95° – 30° or better
 - Vertical FOV: 50° – 20° or better
- Day/Night Mode: True Day/Night with IR Cut Filter (ICR)
- Wide Dynamic Range: 120 dB or higher
- Video Compression: H.265/H.264/MJPEG

- Video Stream: Dual Stream, Mainstream 5 MP @ 25/30 fps
- Audio Compression: G.711 / G.726 / MP2L2 / PCM / MP3 / AAC
- Audio Sampling Rate: 8kHz/16kHz/48kHz
- Motion Detection: Supported with adjustable sensitivity
- On-Board Storage: MicroSD slot (minimum 128 GB supported)
- Network Interface: RJ-45 (10/100 Base-T Ethernet), PoE (IEEE 802.3 af/at)
- Protocols Supported: IPv4, IPv6, HTTP, HTTPS, TCP/IP, UDP, FTP, NTP, DNS, DHCP, SMTP, SNMP, RTP/RTCP, ICMP, IGMP
- API: ONVIF conformant
- Power Supply: 12 V DC $\pm 10\%$, 24 V AC $\pm 10\%$, or PoE
- Power Consumption: Max 15W
- Housing Material: Metal
- Ingress Protection: IP67
- Impact Resistance: IK10 (vandal-proof)
- Operating Temperature: -40°C to $+50^{\circ}\text{C}$
- Certifications: CE, FCC, UL
- Country of Origin: USA, UK, Japan, EU or equivalent (subject to Engineer's approval)

Note: The updated specification for the PTZ camera can be found elsewhere in this document. In addition, the contemporary upgradation of the ANPR camera shall be maintained to comply with the installed system

Motion Detection Camera (MDC)

MDC camera provides continuous monitoring for intrusion, loitering, and vehicle presence with robust motion detection capabilities. It will be part of the automated enforcement or monitoring layer in ALCS. The MDC Camera shall meet the following technical specifications:

- Camera Type: IP Bullet or Dome with enhanced motion analytics
- Image Sensor: 1/2.8" CMOS, Progressive Scan
- Resolution: Minimum 4 MP (2560x1440 or better)
- Minimum Illumination: 0.01 lux (color), 0 lux with IR
- IR Range: ≥ 30 meters
- Shutter Speed: Adjustable, up to 1/15000 s
- Lens Type: Fixed or motorized varifocal (e.g., 2.8–12 mm)
- Aperture: F1.4 or better
- WDR: ≥ 120 dB
- Video Compression: H.265/H.264/MJPEG
- Video Stream: Dual or triple stream
- Motion Detection Features:

- Zone configuration
- Sensitivity control
- Line crossing and intrusion detection
- Audio: Optional, same codecs as Dome
- On-Board Storage: MicroSD slot (128 GB or higher)
- Network Interface: RJ-45 with PoE support
- Event Triggers:
 - Motion detection
 - Tamper detection
 - Line crossing, region entrance/exit
- Power Supply: 12V DC or PoE
- Power Consumption: Max 12W
- Protection Rating: IP67, IK10
- Operating Temperature: -40°C to $+50^{\circ}\text{C}$
- Certifications: CE, UL, FCC
- Country of Origin: USA/UK/Japan/EU or equivalent (subject to Engineer's approval)

Note: The updated specification for the MDC camera can be found elsewhere in this document. In addition, the contemporary upgradation of the MDC camera shall be maintained to comply with the installed system.

7.38.3.10. Equipment cabinets

WIM measurement electronics shall be installed in the outdoor cabinet, which shall safely protect the equipment against any weather conditions and corrosion.

Equipment cabinet used in the Pre-selection sub-system (HS-WIM/MS-WIM) and all other outdoor-type cabinets in other sub-systems in the project shall meet the following requirements:

- Corrosion protection;
- Vandalism-proof, secured with fences and locks
- External alarm system connected to the ALCS operator room for alarms such as door open, intrusion detection, etc. The alarms shall be displayed in Operator Terminals at the Axle Load Control Station and the MAIN CONTROL CENTER.
- IP66 Rated, weatherproof, dustproof
- The size should be enough to accommodate all necessary equipment at the installation site
- Welded design for strength and durability
- Adjustable 19-inch rackmount rails with vertical cable management rings on both sides
- Front Access, 3-point locking system
- Round cable glands with removable rubber covers on the base

- High-grade polyurethane door joint strip
- Earthing bar conveniently located at the front

Equipment cabinets shall be equipped with all necessary accessories for cabling, data, and power connection and distribution.

7.38.3.11. RFID Readers

Ultra-high Frequency (UHF) Radio Frequency Identification (RFID) readers installed at Axle Load Control Station Evasion Sub-system and all other sub-systems shall meet the following minimum requirements:

- Supports SIO 18000 6B, ISO 18000-6C (EPC C1 Gen 2)
- Operating Frequency: 902-928 MHz
- FHSS and Fixed Frequency transmission
- RF Output power up to 32 dBm (adjustable)
- 12 dBi antenna and up to 10 m reading distance (antenna can be integrated or external)
- Support auto-running, interactive, and trigger-activated modes
- RS232, RS485, 10/100M Ethernet ports

7.38.3.12. Vehicle Detectors

For the detection of the vehicle, inductive loop detectors shall be used. A multi-channel inductive loop controller should be used so that one controller can be connected to loops on two (02) lanes and the shoulder lane (In total, three (03) lanes). The vehicle detectors shall also detect the direction of the vehicles. The vehicle detector shall have Level A accuracy as described in section 7.39.35 of the Automatic Traffic Counter and Classifier.

7.38.3.13. Variable Message Signs (VMS)

The VMS signs shall meet or exceed the following requirements:

- The VMS housing shall have a NEMA Type 3R rating
- Characters legible from a distance of 50 meters
- Character height minimum 20 cm.
- Characters to be displayed in amber/yellow color.
- Have a minimum cone of vision angle of 30 degrees from the center
- Manufactured in an ISO 9001-certified facility
- When not energized, the sign shall be completely blanked out without any ghost images.

Additional detailed specifications for VMS shall be followed from Section 7.39 of this Specification.

7.38.3.14. Customized Outdoor Display

As the vehicle moves on the axle load sensor (LS-WIM), the Customized Outdoor Display installed near the Booth shall display the axle loads and the gross vehicle weight so that the driver can see the measurement results as the axles are measured.

The Customized Outdoor Display shall meet the following requirements:

- It shall be a multicolor LED-based display
- It shall be controllable by the Sub-system Local Controller or Lane Measurement and Enforcement Software automatically to display the axle loads and the gross vehicle weight and show the overweight fine information if any.
- It shall be also controllable remotely to Axle Load Control Operators connected to the Axle Load Control Station Computer sub-system
- The characters shall be legible from a minimum 70 m. distance
- It shall be able to display the weight up to minimum 7 axles and the corresponding gross vehicle weight
- It shall display the overload of axle or gross weight if any

7.38.3.15. Uninterrupted Power Supply

The UPS units shall be of Online Uninterruptible Power Supply (UPS) type, designed to provide continuous, stable, and clean power to connected equipment. Each UPS system shall include a central processing unit (CPU) and be capable of operating with an input supply of 160 – 275V AC, single phase, 50 Hz, and deliver an output voltage of 220V $\pm$ 1%, 50 Hz, single phase.

The systems shall include built-in protection features for:

- Lightning and surge protection
- Blackouts and power failures
- Over-voltage and under-voltage
- Overload conditions
- Battery under-voltage and overcharge protection

Each UPS shall provide a minimum backup time of 30 minutes at full load. The units must be complete with necessary batteries, cabling, and accessories for proper installation and operation.

7.38.3.16. Automatic Lane Barrier

Automatic Lane Barriers should have an aluminum stainless cover and shall have a minimum 3 m boom length. The opening and closing times shall be a maximum of 1.2 seconds. It shall include an

automatic opening in case of any obstacle under the boom when closing. Also, it shall have protection against the hits so that the boom opens horizontally to prevent damage to the equipment. In case of power failure, it shall stay open. Further details shall be provided in section 7.37.5.5 of this Specification.

7.38.3.17. Lane Traffic Lights

At the entry of each measurement lane (apron), there shall be a Lane Traffic Light installed. When a vehicle enters the measurement lane, this traffic light shall be turned to “RED” and it shall be turned to “GREEN” after the measured vehicle leaves the measurement lane.

At the exit of the apron (after the booth), there shall be another Lane Traffic Light next to the Automatic Lane Barrier. When the Barrier is opened by the system automatically or by the Booth Operator, this traffic light shall turn “GREEN AHEAD” or “GREEN DIVERT” depending on the overload status of the vehicle.

The traffic lights must have the following characteristics:

- Operating Voltage: 220±20%VAC @ 50 Hz
- Operating Temperature: -40°C~+80°C
- Working Humidity: ≤95%
- Visibility Range: 20 m (under normal visibility conditions)
- Size: 300 mm X 300 mm
- Visibility Range: 150 m (under extreme weather conditions)
- LED: 5mm in diameter, 8000 mCd
- Enclosure: IP 65 or Higher

7.38.3.18. Axle Load Control Station Server (with OS)

Axle Load Control Station Server shall meet the following specifications or equivalent minimum:

Supply, installation, testing & commissioning of the server with specifications or equivalent as per the direction of the Engineer in charge.

- Two (2) Intel Xeon Scalable Processors, the processors should have a minimum 2.3GHz clock speed & 20 cores each.
- Must have at least 30 MB L3 Cache. Should support up to two 3rd Gen Intel Xeon Scalable processors (with up to 40 cores per socket).
- Intel chipset compatible with the processors and supports up to two GPUs.

- The server should have 4 Nos 1.2 TB 12G SAS 10K RPM SFF HDD and should support up to 10 SAS/SATA or NVMe disk drives along with M.2 boot options up to 960 GB with optional hardware RAID.
- RAID controller should support RAID 0, 1, 5, 6, 10, 50, and 60 with a minimum 4CB FBWC (16Drive) write cache module.
- Should have at least 32x DDR4 DIMMs for up to 4 TB of capacity using 128 CB DIMMs, or 16x DDR4 DIMMS + 16x Intel Optane persistent memory modules for up to 10 TB of memory with a minimum 64 CB of DDR4 Memory.
- Support for advanced memory redundant technologies like Advanced Error Correcting Code (ECC) and memory mirroring.
- Should have 2*10 GbE (embedded) Base T LAN ports with Intel i350 Quad Port 1Gb Adapter up to 3 PCIe 4.0 slots plus a modular LAN on Motherboard (mLOM) slot
- Should support out-of-band upgrades, Agentless out-of-band management.
- integrated diagnostics and Power monitoring and reporting.
- Should support industry-standard management protocols like IPMI v2 and SNMPv3.
- Cloud operations platform that consists of optional, modular capabilities of advanced infrastructure and workload optimization.
- One 1-Gbps RJ-45 management port
- Multiple management interfaces, including web user interface and command line interface, and Hardware policy-based security
- Should support anti-counterfeit measures to guarantee authenticity, System
- Lock Down, Secure Debug BIOS and BMC Comms.
- 1 serial port, 2 USB 3.0 ports, MA video port
- Hot-swappable redundant fans
- The server should have Redundant Power Supplies, including Rail Kit and cable management.
- Should support Microsoft Windows Server, Red Hat Enterprise Linux (RHEL), SUSE Linux Enterprise Server (SLES), and VMware.
- Form Factor: Rack-mountable and maximum 1U
- 42U Rack assembly with 4 AC cooling fans, perforated removable front door with a lock, one rear door, superior ventilation, min. Four nos. of heavy-duty feet/wheel posts, min. Two nos.. power strips having min. Six outlets each (16 Amp)
- KVM Switch: The KVM switch shall have a minimum of 8 ports with an expandability feature to support future scalability. It shall include 8 KVM-to-server connecting cables and support console input via keyboard and pointing device (mouse or touchpad). The device shall have a 1U rackmount form factor and be supplied with the necessary mounting kits. Interface compatibility must include PS/2, USB, and VT100 adapters. The unit shall be powered and equipped with a cooling fan to ensure stable performance under continuous operation.

- Server Room UPS 10kVA (60 mins battery backup): A 10kVA Online UPS shall be provided for the server room, complete with a central processing unit capable of operating with an input voltage range of 160 – 275V AC, single phase, 50 Hz, and delivering a stable output of $220V \pm 1\%$, 50 Hz, single phase. The UPS shall include comprehensive protection features such as lightning and surge protection, blackout handling, over- and under-voltage protection, overload protection, and safeguards against battery low and overcharging. The system must ensure a minimum backup time of 60 minutes at full load, and include all necessary batteries, cabling, and accessories for a reliable and uninterrupted power supply.

Additionally, the requirement for server room environment (temperature, humidity, dust control, etc.), fire detection and protection system, access control system, security, and others shall be met as per the minimum standard specified in Section 7.330 of this Specification or as approved by the Engineer.

7.38.4. Requirements for the ALCS System (Software)

7.38.4.1. Axle Load Control System architecture and communication

The Contractor shall implement an Axle Load Control System, the purpose of which is to enforce axle load and gross vehicle weight/axle weight limit violations by measuring the axle loads and gross vehicle weights of the trucks, calculating the fine following the regulations, with central monitoring and auditing functions. The supplied system shall be able to calculate and generate the violation fines according to the legislation in Bangladesh (Section 7.38.1), and the descriptions detailed in the next section. The system shall also generate traffic data, which then can be used for traffic monitoring, road design, road maintenance planning, traffic planning, etc.

Figure 7.38-2 shows the overall high-level architecture of the Axle Load Control Station (ALCS) system. It shall consist of High-Speed/Medium-Speed WIM Sites for pre-selection purposes, Low Speed-WIMs/Static Scales, and other ITS equipment and software for measuring and enforcing axle loads installed at Axle Load Control Stations, Axle Load Control Back Office System (at Axle Load Main Control Centre), and different data communication and IT systems.

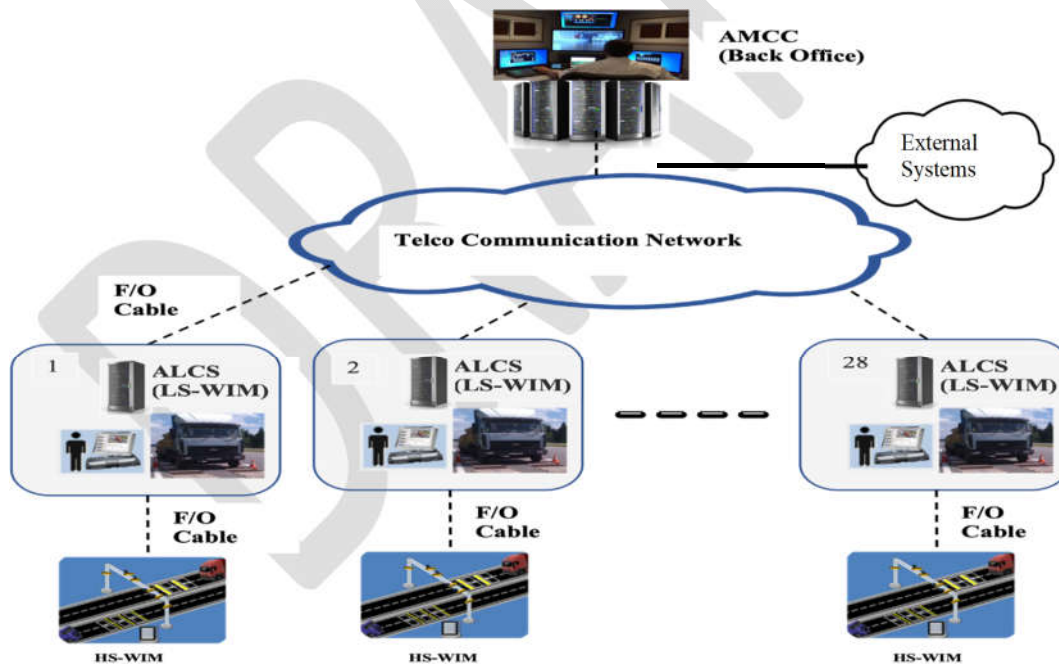


Figure 7.38-2: Axle Load Control System Architecture.

7.38.4.2. Axle Load Control Sub-systems

The Main Subsystems of the Axle Load Control System are as follows:

- Pre-selection Sub-system (HS-WIM/MS-WIM)

- Station Evasion Control Sub-System
- Axle Load Control Station Computer Sub-System
- In-Station Truck Traffic Management Sub-System
- Axle Load Measurement and Enforcement Sub-System (LS-WIM/Static Scale)
- Axle Load Control Main Control Centre Sub-system
- Video Surveillance Sub-system
- IT Network Sub-System

The basic operation principle will be as follows:

- **Preselection sub-system:** The HS-WIM/MS-WIM shall be installed at a distance of 1-3 km before the Axle Load Control Station to detect and identify all of the vehicles through the system on the mainline road at highways speeds (up to 130 kmph), measure each axle weight, axle group weight, and gross vehicle weight with 90% accuracy (equivalent to Class B (10) as in Table 7.38.4) and create a data package including all measured vehicle parameters using RFID readers and ANPR cameras (or by means of machine learning algorithm if RFID readers and ANPR cameras fail to detect). For a group of axles, single axles, and the axle of a group, the accuracy of the same class shall be adhered to. Then this data package shall be sent to the Axle Load Control Station Computer Sub-system via the IT Network Sub-system.
- **Station Evasion Control Sub-System:** Normally, all commercial vehicles (trucks and buses) must enter the Axle Load Control Station regardless of whether they are overweight or not. To detect and identify evaders of the Axle Load Control Stations, on the mainline between the entry and exit ramps of the Axle Load Control Station, there shall be a Station Evasion Control Sub-system installed. This sub-system shall identify the vehicles by using RFID readers and ANPR cameras (or by means of a machine learning algorithm if RFID readers and ANPR cameras fail to detect) and shall take a photo of every vehicle passing through and send it to the Axle Load Control Station Sub-system via the IT Network Sub-system.
- **In-Station Truck Traffic Management Sub-System:** At the entrance to the weighing zone of the Axle Load Control Station, there will be an ANPR camera, VMS, and the controller, which is connected to all this equipment and the Axle Load Control Station Computer Sub-system. This equipment will be installed on 1 or 2 lanes, depending on the type of the station, at the entry to the weigh zone. The sub-system will detect the license plate of the vehicle by using the ANPR camera (or by means of a machine learning algorithm to detect class and then manual entry for number plates) and interrogate the license plate from the Axle Load Control Station Computer Sub-system to check if the vehicle is screened as overweight or not. If not overweight, then it will direct the vehicle to the bypass lane, and otherwise to the measurement (LS-WIM) lanes. At the exit of the station, there will be some other equipment which is part of the Traffic Management Sub-system: Automatic Lane Barrier(s), RFID reader(s), ANPR camera(s), and a controller. Suppose the vehicle identified by the RFID reader and/or ANPR camera and/or machine learning algorithm is not overweight according to HS-WIM or LS-WIM measurements (to be checked from Axle Load Control Station

Computer Sub-system data when the vehicle comes to the exit). In that case, the barrier will be opened, and otherwise, it shall stay closed.

- **Axle Load Measurement and Enforcement Subsystem (LS-WIM):** The LS-WIM/Static Scale, which is installed at measurement lanes in the weighing zone, shall measure each axle's weight, axle group weight, and gross vehicle weight of all of the vehicles passing through the system at speeds between 0 kmph and 10 kmph. The accuracy of the measurements shall be a minimum 98%. If the vehicle is measured as not overloaded, the controller shall automatically open the barrier at the exit of the lane. If the vehicle is overloaded, the software application on the lane shall automatically calculate the fee based on the fee structure and the overweight amount. The payment options can be cash, credit card, debit card, or via a mobile financial service (MFS) application. After the payment of the fine, the driver shall be given a receipt with a unique receipt ID including measurement data printed, as well as a QR Code on the receipt. The truck driver shall be requested to go to the warehouse to unload the excess weight by the Lane Operator. After unloading, the truck shall be re-weighed, and the above process shall be repeated. When unloaded goods are picked up by the same or another truck, the weight violation ticket given before has to be used. The booth operator shall scan the QR Code on the receipt, and the application shall automatically calculate the fee for storing the excess load in the warehouse by using the following parameters: Initial measurement weight (read from QR-Code), initial measurement time (read from QR-Code), re-measured weight after unloading excess weight, re-measurement time, the tariff for storing (per kg per hour). The driver shall pay the warehouse fee and leave the lane.
- **Axle Load Control Station Computer Sub-System:** Axle Load Control Station Computer Sub-system shall receive the data package from HS-WIM/MS-WIM and decide if a vehicle is overweight or not, and, based on this, it shall manage the In-station Traffic Management System to direct the vehicles to measurement lanes or by-pass lane(s). Moreover, it shall get and store the measurement, fine, and collection data for each vehicle from LS-WIMs. Axle Load Control Station shall also receive the data from Station Evasion Control Sub-system and match the IDs of the vehicle coming from the Evasion Control Sub-system and HS-WIM/MS-WIM, and get the vehicle class to determine if there is any commercial vehicle not entering the Station. If there is any such vehicle, this data shall be recorded as a violation and sent to the Axle Load Main Control Centre for further processing. Axle Load Control Station Sub-system shall also monitor the status and manage the configuration of all equipment/software in the Axle Load Control Station. It shall also include an application for cash up of the collected fees at the end of each shift by the Booth Operator
- **Axle Load Control Main Control Centre Sub-system:** Axle Load Control Back Office Sub-system shall collect, store, process, and report all of the data generated by all the Axle Load Control Stations. It shall also have an application for citation management of axle load control station evasions. Moreover, it shall manage and follow the payment of deferred overweight violation fines and generate new fines if the fines are not paid on time. It shall also monitor the status of all networks, equipment, and

sub-systems. Furthermore, it will serve as the integration point with external systems/stakeholders such as BRTA.

- **Video Surveillance Subsystem:** For the safety of the ALCS sites, there shall be a CCTV system network to monitor all the sub-systems of the station.

In Station Building, to secure inside the areas such as the Server room, control room, office lobby, and the whole ground floor, indoor Dome and Bullet cameras shall be used. The PTZ camera is considered to secure the surrounding environment in the four corners outside of the building.

In station territory, in the measurement lane, the Evasion Control site, and inside the tool booth, Bullet and outdoor Dome cameras shall be used.

To secure the warehouse inside and outside, including the parking area, outdoor/indoor dome cameras and bullet cameras shall be considered.

CCTV cameras, such as the outdoor dome and PTZ, shall be installed for the direction of the roadside cabinet, which will be installed on top of the gantry at the WIM location.

Two Network video recorders (NVRs) with 32 channels and 20 TB storage capacity shall be supplied and installed to cover all the CC cameras, including HS WIM. These NVRs will store the data of CCTV cameras. NVR may have a configurable option, such as if there is no movement, it will not store data. These devices shall be connected to the LAN so that the MAIN CONTROL CENTER can easily access these devices for a specific task. NVR at the Stations shall store 3 months of video surveillance data.

- **IT Network Sub-System:** All of the communication between different sub-systems shall be via the IT Network Sub-System installed within the scope of the project. There shall be a Local Area Network (LAN) at each Axle Load Control Station to connect all equipment, including HS-WIM/MS-WIM, and each Axle Load Control Station shall be connected to the Back Office via a Wide Area Network (WAN) provided by Telecommunication Service Providers.

Details of the required operation, equipment, and specifications of these sub-systems are stated in the following sections. It shall be noted that some equipment and material will be used in more than one sub-system. For such equipment and material, the requirements are mentioned only once at the first instance of such equipment and material, and the requirements are not repeated in other sub-systems in which the same equipment and material shall be used. The same requirement applies to the same equipment and material in all sub-systems.

7.38.4.3. Pre-selection Subsystem (HS-WIM)

High-speed WIMs/ Medium-speed WIMs shall be used for the pre-selection of the overweight vehicles, and they will be installed on the mainline (1-3 km before the Axle Load Control Station). These WIMs shall be able to detect all of the vehicles (not only trucks but all vehicle classes) passing through the WIM Site and measure the axle loads and gross vehicle weight of each vehicle, regardless of whether the vehicle is overloaded or not. Also, the system should

be able to identify each vehicle by using ANPR cameras (or by means of a machine learning algorithm if ANPR cameras fail to detect number plates). Machine learning based identification shall be overridden by the ANPR camera reading (if available) in all cases.

Pre-selection Subsystem Components

Pre-selection Sub-system (HS-WIM/MS-WIM) per each site shall comprise at least the following:

- Roadside outdoor Cabinet for WIM electronics;
- Weight sensors measuring axle weight, axle group weight, single vehicle gross weight, road train gross weight, and detecting single/double wheels;
- Necessary cabling and mounting hardware for each lane to be instrumented;
- Sufficient axle sensors per lane to determine vehicle speed and axle spacing;
- A vehicle detector per lane, such as an inductive loop detector, to separate vehicle events and count vehicles;
- Automatic Number Plate Recognition (ANPR);
- A local processing unit (LPU) with a class detection system using a machine learning algorithm. The algorithm shall be trained on a wide variety and sufficient number of vehicles to achieve 95% accuracy in detection;
- UPS with 30 min. battery backup, min 3k KVA (power rating should be such that it supplies power to all equipment at the station simultaneously);
- All necessary interconnecting cables and miscellaneous materials to make an operational system.

The IT Network Sub-system shall provide the connection between the Pre-selection subsystem and other sub-systems. Also, the Pre-selection subsystem site shall be secured by Motion Detection Camera (MDC) and/or CCTV cameras of the Video Surveillance sub-system.

The ALCS shall comprise all necessary hardware and software for collecting, processing, storing, and transmitting all information to the Axle Load Control Station Computer Sub-system, and for receiving and processing required data from the Axle Load Control Station or the MAIN CONTROL CENTER.

Pre-selection Subsystem Data

Pre-selection Sub-system at each site (HS-WIM) shall create a package of data for each vehicle, and each data package will be composed of the:

- HS-WIM site identity;
- HS-WIM site crossing date and time;
- License Plate Number reading data by ANPR Camera;
- Photo(s) of the license plate;
- Lane number used by the vehicle;
- Overview camera photo;
- Vehicle speed;

- Vehicle length;
- Number of axles
- Axle spacing;
- Vehicle classification by Table 14;
- Single tire / dual tire identification;
- Axle weights and axle group weights;
- The gross weight of the vehicle;
- ESAL value;
- Screening Decision. (The criteria/threshold for screening decision should be settable by the operator)

After creating the data package for each vehicle passing, the Pre-selection Sub-system shall send it to the Axle Load Control Station. Pre-selection Sub-system shall be capable of operating independently of the ALCS Station as well, and therefore shall provide stand-alone data accumulation in case of any network failure, and accumulated data shall be sent to ALCS when the network failure is recovered.

To provide data safety and protection from unauthorized access, all vehicle photographic records generated and stored shall be automatically deleted from the Pre-selection sub-system (at the site) within a predefined time period (parameterized variable).

Pre-selection Subsystem Measurement Accuracy

The WIM accuracy specification and testing follow the principles of the COST 323 European WIM Specification. The detailed Customer Acceptance Test methods and procedures shall be agreed upon between the Employer and Contractor, and they shall be documented in the Test Plan.

The extent of the measurement accuracy tests shall be equivalent to the Test Plan No. 2.2 of the COST 323 European WIM Specification. The fulfilment of the installation site pavement requirements as specified in COST 323 is the responsibility of the Contractor as mentioned in the Scope of Works section above.

COST 323 accuracy class tolerances are listed in Table 7.38-4. The Pre-selection Sub-system shall preferably meet B(+7) accuracy class requirements and minimum B(10) accuracy class requirements for measurement of axle loads, gross vehicle weight, axle spacing, and vehicle speed. The specified measurement accuracy shall be reached for a vehicle speed range of 30 – 130 km/h.

Accuracy requirements for the WIM ambient temperature measurement are:

- Air Temperature measurement range shall be -40°C ... +70 °C
- The accuracy of the WIM Site Air Temperature measurement shall be $\pm 0.5^{\circ}\text{C}$ in the range -40°C to +70 °C

Pre-selection Subsystem Other Requirements

Pre-selection sub-system shall meet the following requirements at each site:

- WIM Site shall be able to process and store the data for at least 7 days for a minimum

of 50,000 vehicles/day.

- WIM System shall be capable of processing information about vehicles and road trains with 2-15 axles
- Weighing shall be performed by weighing sensors at each traffic lane
- Each axle load shall be measured at least at a minimum of 2 consecutive points. To meet the accuracy requirements, the Bidder might propose more than two measuring points, in case the proposed solution cannot meet the measurement accuracy requirements by using two measurement points.
- Weigh sensors shall cover the entire lane (lane width 3,70 m), and the HS-WIM/ MS-WIM design shall detect bypassing the sensors along the shoulder in the area of HS-WIM/ MS-WIM installation
- Weight sensor capacity shall be min. 20 tons per axle
- Weight sensor ultimate load shall be min. 30 tons per axle without mechanical and electric damage
- Weight sensor technology should be either a strain gauge strip or a piezo-quartz bar type
- All Pre-selection Sub-system Components shall be protected against overvoltage.
- All Pre-selection Sub-system components shall fulfil the EMC requirements (Directive 2014/30/EU)
- The Pre-selection Sub-system shall provide an option to monitor and control the equipment and the system, and to get measurement and statistics data remotely from the ALCS Station or the Main Control Centre.

7.38.4.4. Axle Load Control Station Evasion Control Sub-System

The station Evasion Control Sub-system shall identify the vehicles by reading the RFID tags and the license plate of the vehicles by ANPR Camera (or by means of a machine learning algorithm if RFID readers and ANPR cameras fail to detect). This sub-system shall detect, identify, and take photos of every vehicle passing through the site and send them to the Axle Load Control Station Computer Sub-system via the IT Network Sub-system, in a data set.

The sub-system shall consist of:

- ANPR Camera (with the requirements mentioned above);
- RFID Reader;
- A local processing unit (LPU) with an axle class detection system using a machine learning algorithm. The algorithm shall be trained on a wide variety and sufficient number of vehicles to achieve 95% accuracy in detection;
- Overview camera for taking overview photos of vehicles from the front and the side, showing the entire vehicle/road train;
- Vehicle Detection System (Loop and loop controller);
- Local Controller;
- UPS with 30 min. battery backup, min 1k KVA (power rating should be such that it supplies power to all equipment at the station simultaneously);
- Roadside cabinet;

- Necessary cabling and mounting hardware for each lane to be instrumented.

The data set sent to the ALCS for each vehicle shall be composed of:

- Site identity;
- Date and time;
- Lane number;
- License Plate Number;
- Overview photos of vehicles from the front and the side showing the entire vehicle/road train;
- Close-up photograph of the number plate to be identified by a human operator.

License Plate Number reading from the RFID tag of a vehicle shall prevail over the ANPR camera reading in all cases. Machine learning based identification shall be overridden by the ANPR camera reading or RFID tag reading in all cases. On the other hand, in case the difference between the RFID reading and ANPR reading is more than one (01) character, the data set should be marked with a flag so that it can be checked by the Main Control Center Back Office staff manually to determine the reason for the difference and act accordingly.

The sub-system shall detect 99% of the vehicles and shall identify (read the license plate and/or RFID tags) 95% of the vehicles passing through.

The Sub-system Local Controller shall include the necessary software to ensure the operation of the Sub-system according to the requirements defined above.

Axle Load Control Station Evasion Control Sub-System Cabinet

Evasion Control sub-system controllers and other necessary equipment shall be installed in an outdoor cabinet, which shall safely protect the equipment against any weather conditions and corrosion.

The equipment cabinet used in Axle Load Control Station Evasion Control Sub-System shall meet the technical requirements of the outdoor type cabinets defined in the Pre-selection Sub-system Section.

7.38.4.5. In-Station Truck Traffic Management Sub-System

In-Station Truck Traffic Management Sub-system shall divert the trucks to bypass lanes or weight measurement lanes at the entrance to the weighing area. Also, it shall control the trucks exiting the weighing station.

In-Station Truck Traffic Management Sub-System at the Station Entry

The sub-system shall have the following equipment on two lanes at the entrance of the Axle Load Control Station:

- ANPR Camera;
- A local processing unit (LPU) with an axle class detection system using a machine learning algorithm;

- Variable Message Sign (VMS);
- Vehicle Detection System (loop and controller);
- Roadside Cabinet;
- Local Controller;
- All necessary cabling and accessories.

When the Vehicle Detection System detects the vehicle, the ANPR Camera should be triggered and read the license plate (or by a machine learning based alternative process). Then the controller shall query the HS-WIM/MS-WIM screening decision for that License Plate Number from the Axle Load Control Computer Sub-system. If the vehicle is not overweight according to HS-WIM/MS-WIM measurement, then it shall direct the vehicle to the By-Pass Lane by showing the message on the VMS. Similarly, if the vehicle is overweight according to the HS-WIM/MS-WIM measurement result, then it shall direct the vehicle to the measurement lanes.

For directing the traffic to appropriate lanes, the information to the driver shall be given via Variable Message Signs (installed on two lanes in Type A stations and on one lane in Type B and C stations) at the entry. The VMS sign system shall direct vehicles to enter the weighing area or use the bypass lane, based on the results of the HS-WIM/MS-WIM screening decision. The system shall be designed to ensure that only the vehicle for which the message is intended shall see the message on the VMS.

VMS Sign shall provide the following two messages depending on the screening decision:

Message 1 (Report Message with a diversion arrow):

{LICENSE PLATE NUMBER}
ENTER WEIGH STATION

Message 2 (Bypass Message with straight arrow):

{LICENSE PLATE NUMBER}
BYPASS WEIGH STATION

If the ANPR camera (or alternative process) cannot read the license plate or make a screening decision for the read license plate, then the following message shall be displayed:

Message 3 (Bypass Message with diversion arrow):

TRUCK MUST
ENTER WEIGH STATION

The ANPR cameras, LPU, and VMS Signs shall be installed adjacent to the lanes on the entry to the weighing area (when there are two (02) lanes in total).

The Local Controller shall include all necessary hardware and software to ensure the operation of the Sub-system as defined above.

The sub-system shall detect a minimum of 99% of the vehicles and shall identify a minimum of 95% of the vehicles properly by ANPR Camera or an alternative process.

In-Station Truck Traffic Management Sub-System at the Station Exit

There shall not be any barrier on the bypass lane. The control of the vehicles shall be done at the exit of the station by the In-Station Truck Traffic Management Sub-system. At the exit of the station, the following equipment shall be installed:

- ANPR Camera
- RFID Reader
- A local processing unit (LPU) with an axle class detection system using a machine learning algorithm.
- Automatic Lane Barrier
- Vehicle Detection System (loops and controller)
- Alarm/Siren (connected PA system)
- Local Controller
- Roadside cabinet
- All necessary cabling and accessories

When a vehicle comes to the exit lanes of the Axle Load Control Station, the ANPR and/or RFID readers and/or LPU installed on the lanes shall detect the license plate and the controller shall query from the Axle Load Control Computer sub-system, and open the Automatic Lane Barrier only if the vehicles are measured and decided by HS-WIM/MS-WIM as not exceeding weight limits (axle or gross weight) or LS-WIM/Static Scale measurement confirms that the vehicle is not overloaded. It shall be noted that there might be more than 1 (one) LS-WIM/Static Scale measurement for the same vehicle in case a vehicle is overloaded and re-measured after unloading. In such cases, the latest LS-WIM/Static Scale measurement result shall be taken into consideration.

The system shall detect tail-gaiting and unauthorized escape of a vehicle from the station and run the siren. Axle Load Control Computer Sub-system shall generate a violation notice for that vehicle and send it to the Main Control Center so that it can generate a violation fine.

The Local Controller shall include all necessary hardware and software to ensure the operation of the Sub-system as defined above.

7.38.4.6. Axle Load Measurement and Enforcement Sub-System

Axle Load Measurement and Enforcement Sub-system shall be installed on each station's axle load measurement lane. It shall measure the axle loads, axle group loads, gross vehicle weight, vehicle speed, vehicle size, etc., calculate and collect the fine if the vehicle is overloaded, and direct the vehicle to the unloading area or exit of the station.

Axle Load Measurement and Enforcement Sub-System Components

The Axle Load Measurement and Enforcement Sub-system shall include the following on each lane as a minimum:

- Roadside outdoor Cabinet for LS-WIM electronics;
- LS-WIM electronics;
- LS-WIM Weight sensor (3m width) measuring axle weight, axle group weight, single

vehicle gross weight, road train gross weight, and Tyre sensor detecting single/double wheels;

- Sufficient axle/vehicle detectors per lane, such as an inductive loop detector and/or optical curtain, to separate vehicle events (such as entering the weighing lane, exiting the weighing lane, waiting in front of the Booth, etc.), to count vehicles, to determine vehicle speed and axle spacing, and vehicle classification;
- Automatic Number Plate Recognition (ANPR);
- RFID Reader;
- A local processing unit (LPU) with an axle class detection system using a machine learning algorithm. The algorithm shall be trained on a wide variety and sufficient number of vehicles to achieve 95% accuracy in detection;
- Lane overview camera for taking overview photos of vehicles;
- Lane Traffic Lights;
- Customised Outdoor display;
- Sub-system Local Controller;
- Booth Operator Terminal and Axle Load Measurement and Enforcement Software;
- Receipt printer;
- Automatic Lane Barrier;
- UPS with 30 min. battery backup, min 1k KVA (power rating should be such that it supplies power to all equipment at the station simultaneously);
- All necessary interconnecting cables and miscellaneous materials to make an operational system;
- Corresponding system shall be installed if a Static scale is used instead of LS-WIM.

Axle Load Measurement and Enforcement Software

Axle Load Measurement and Enforcement Software shall receive the data from LS-WIM/Static Scale and all sensors, and calculate the fine automatically if there is any overloaded axle or axle group or if the gross vehicle weight is above the limits.

On the operator terminal, the following data shall be displayed:

- a) Automatically recognized registration plate number;
- b) Vehicle speed;
- c) Number of axles and axles spacing;
- d) Single tire / dual tire identification;
- e) Axle weights and axle group weights;
- f) Axle or axle group overweight
- g) Gross weight;
- h) Gross overweight
- i) Side photograph of the entire vehicle with a distinguishable number of axles of the vehicle;
- j) Close-up photograph of the number plate to be identified by a human operator;
- k) Automatically calculates the overweight fine if there is any;

- 1) Outstanding overweight or evasion payments of the vehicle from previous controls or other Axle Load Control Stations.

During the measurement of the axle loads, the automatic lane barrier shall stay closed, and the traffic control signal shall be read. If the vehicle is not overloaded, the Automatic Lane Barrier shall be opened automatically, the traffic signal shall turn to GREEN AHEAD, and the vehicle leaves the lane and proceeds to the exit of the station. However, if the vehicle speed during measurement is above 10 kmph, then the Customized Outdoor Display shall display the message “RE-MEASURE”. The barrier shall be opened automatically, and the traffic control signal shall turn to GREEN DIVERT. The lane software shall record this measurement as “INCOMPLETE” and shall not generate any weight measurement data for that truck.

If the automatic license plate recognized by the ANPR camera, RFID reader, or LPU is different from the real license plate of the vehicle, the operator shall be able to change the license plate reading manually, but the system shall leave an audit trail for this change.

When the vehicle is overloaded, the following payment methods shall be available:

- Credit card/debit card (accepting Nexus, Visa, and Mastercard)
- Cash
- Mobile Financial Services application

The system shall be ready to add other electronic means of payment (prepaid or post-paid) by using RFID tags installed on the vehicles.

Therefore, there shall be credit card/debit card readers supplied and installed at toll booths. Credit card integration with a bank shall be done by the Contractor.

QR-Code readers must be used for mobile cash payments. Integration with the Mobile Financial Service providers shall be done by the Contractor.

QR-Code readers shall have the following characteristics:

- Processor: Application & Crypto processor Cortex A5, Memory:256 MB Flash,
- 128 MB RAM, OS: Telium TETRA, SIM:2 SIM, SAM:2 SAM,
- Card Reader: Magstripe Smart card, NFC/Contactless
- Display: Colour,
- Keyboard: 16 keys, raised marking, backlit,4 Functional Keys without backlight,
- Dial-up Modem RJ45, Ethernet 10/100 base T RJ45,
- Terminal Connections: Micro USB Host & Slave, RS 232 RJ11, Dedicated power jack
- Battery: Li-ion 2200mAh, Terminal Size: Portable, Hybrid, Terminal+ Battery: 320g
- Security: PCI PTS 5.x online & offline certified

The system shall display outstanding overweight or evasion payments of the vehicle from previous controls or other Axle Load Control Stations so that the Operator asks for payment of such previous events.

After the payment, the Operator shall print a receipt including the following data:

- Station Name, location

- Data and time
- License Plate Number
- Axle Loads for each axle and axle groups
- Gross weight
- Overloaded axle(s)
- Gross overweight
- Fine amount paid
- QR Code of the ticket, including measurement data

The Receipt printer shall be a thermal printer and shall be able to print both graphics and text at a speed of 200mm/second. It shall have a minimum 180x180 DPI. The printers shall include an auto-cutter.

If the driver cannot pay the fine by any of the means above, then the system shall issue a “Weight Violation Ticket” and the software sends the details of the transaction to the MAIN CONTROL CENTER, Citation Management Module. The same data for the payment receipt shall be printed and given to the driver, but marked in the system as “unpaid”. The Weight Violation ticket data sent to MAIN CONTROL CENTER shall include the following data:

- Station Name, location
- Data and time
- License Plate Number
- Speed of the vehicle
- Axle Loads for each axle and axle groups
- Gross weight
- Overloaded axle(s) measurement result
- Gross overweight
- Close-up photograph of the license plate of the vehicle
- Side and front photographs of the vehicle
- Fine amount to be paid (automatically calculated by using the fine tariff table managed by Main Control Center)
- Due date of the payment (Due date shall be added automatically by using the parameter set by Main Control Center)

After the driver pays the fine or receives the “Weight Violation Ticket” from the Booth Operator, the vehicle must go to the unloading area to unload and re-measure. The Operator shall open the barrier manually, and the traffic control signal at the exit of the lane shall turn to GREEN DIVERT. After the vehicle unloads, the measurement shall be repeated.

In case the driver objects to the measurement result, a re-measurement right shall be given to the driver and this measurement result shall be recorded in the system as “INCOMPLETE”, however, all the measurement results shall be recorded by the system. The measurement shall be repeated in static mode (if the driver wishes so), where the vehicle stops on the weigh beam on each axle and proceeds to the next axle after the measurement of the axle is complete.

Axle Load Measurement and Enforcement Software shall also have a module for the calculation of the storage of the excess weight in the warehouse. This module should work as follows:

When unloaded goods are picked up by the same or another truck, the receipt or the Weight Violation Ticket given before has to be used. If the receipt or Weight Violation Ticket list is selected, the system shall have the option to search the records by using the license plate of the overloaded vehicle. The booth operator will scan the QR Code on the receipt/ticket, and the application shall automatically calculate the fee for storing the excess load in the warehouse by using the following parameters:

- Initial measurement weight (read from QR-Code and verified from the data stored in the system for the transaction),
- Initial measurement time (read from QR-Code and verified from the data stored in the system for the transaction),
- Re-measured weight after unloading excess weight (read from QR-Code and verified from the data stored in the system for the transaction),
- Date/time of the picking up of the goods from the warehouse,
- Tariff for storing (per kg per hour).

The driver will pay the warehouse fee and leave the lane.

The Axle Load Measurement and Enforcement Software shall not allow modification of any data (other than the license plate number in case there is a mismatch between the ANPR reading and the real license plate number of the vehicle) by anyone by any application. Also, data and files generated by the Axle Load Measurement and Enforcement Software shall not be allowed to be deleted by any user or administrator of the ALCS system. Such data and files shall be stored and processed by the system as read-only. The data shall be sent to the Axle Load Control Station Computer Sub-system and the MAIN CONTROL CENTER for processing, reporting, and archiving.

Axle Load Measurement and Enforcement Sub-System (LS-WIM) shall be able to work in isolated mode well with all measurement and enforcement functionalities in case there is a network or communication failure between Axle Load Measurement and Enforcement Sub-System and other sub-systems.

Axle Load Measurement and Enforcement Software shall be installed on a terminal with the following requirements:

- Processor: 10th Generation Intel® Core™ i5-10505 12MB Cache, 6 Cores, 12 Threads, 3.2GHz to 4.6GHz, 65W;
- Chipset: Intel Q470 Chipset or equivalent;
- Clock Speed: Base 3.2 or higher;
- Integrated Audio: Integrated High-definition Audio Codec with internal speaker;
- NIC: Integrated Gigabit LAN;
- Memory: 8GB DDR4 Memory 2666Mhz and supportability up to 64GB;
- Hard Drive: 1TB SATA HDD and expandability up to 4TB HDD;
- Monitor: Same Brand 17.37" LED, same brand as the computer offered with a Display

- port;
- Mouse: USB Optical Mouse, same brand as the computer;
- Keyboard: USB Keyboard of the same brand;
- Graphics: Integrated Intel UHD Graphics 630;
- OS: Microsoft Windows 10 Pro;
- Ports: 1 RJ-45 port 10/100/1000 Mbps (rear);
- Minimum 8 USB ports;
- 1 Universal Audio Jack (front);
- 1 Line-out audio port (rear, restackable);
- 2 DisplayPort 1.4 (rear);
- Chassis: Tower;
- Power Supply: Minimum 260 W, typical 85% Efficient PSU;
- System Power Cord: System Power Cord;
- Certifications: DT should be Military Standard, ISO, and FCC certified.

LS-WIM/Static Scale Data

When the vehicle enters the lanes, vehicle detection loops shall detect the vehicle and activate the other equipment in the lane. If there is another vehicle in the LS-WIM/Static Scale measurement area, the traffic signal light shall be turned to RED. When the weighing area becomes empty, the traffic signal light shall be turned to GREEN and the vehicle will continue at the speed limit. The LS-WIM/Static Scale sensor shall measure the axle loads, group axle loads, and gross vehicle weight as the vehicle passes over the LS-WIM/Static Scale sensor.

The LS-WIM/Static Scale system shall create a data set for each vehicle, and the data set should include the following data:

- a) Lane crossing date and time;
- b) Lane number;
- c) Automatically recognized registration plate number;
- d) Vehicle speed;
- e) Number of axles and axles spacing;
- f) Vehicle class;
- g) Single tire / dual tire identification;
- h) Axle weights and axle group weights;
- i) Axle or axle group overweight
- j) Gross weight;
- k) Gross overweight
- l) Front photograph of the vehicle;
- m) Side photograph (by using lane overview camera) of the entire vehicle with a distinguishable number of axles of the vehicle;
- n) Close-up photograph of the number plate to be identified by a human operator;

Measurement Sensors and Accuracy Requirements

LS-WIM/Static Scale shall measure the axle loads with load cells. It shall measure the axle both in dynamic (up to 15 kmph) and static modes. The width of the weigh beam shall be 3m, and it shall have a robust steel construction that has been treated against corrosion. Moreover, it shall be designed such that the surface is level and that firm contact is made at all points of support, so that good load distribution is maintained at all times.

The sensors must be installed on the existing concrete pavement following the installation guidelines of the manufacturer by trained staff.

LS-WIM accuracy requirements and testing follow the principles of the International Organization of Legal Metrology (OIML R 134) as described in section 7.38.2.2 of this Specification. The equipment proposed must have the necessary OIML R 134 certification, and it shall be provided in the proposal of the Bidder.

Minimum Required Gross Weight OIML R 134 Accuracy Level: $\pm 2\%$

Corresponding Minimum Required Axle Load or Axle Group Accuracy Class: E ($\pm 5\%$)

The accuracy levels in static mode shall be minimum Class III as described in Table 7.38-6.

The weight sensor capacity shall be a minimum. 20 tons per axle, and the sensor's ultimate load shall be a minimum 30 tons per axle without mechanical and electric damage.

Axle counting and vehicle classification system shall meet the following requirements:

- Axle detection: 100%
- Allowed maximum speed measurement error: 2%
- Allowed maximum axle spacing measurement error: 2%

The detailed Customer Acceptance Test methods and procedures shall be agreed upon between the Employer and Contractor, and they shall be documented in the Test Plan.

The extent of the measurement accuracy tests for LS-WIM/Static Scale shall be equivalent to the tests defined in OIML R 134.

7.38.4.7. Axle Load Control Station Computer Sub-system

Sub-system Description and General Requirements

The Axle Load Control Station Computer Sub-system shall be composed of software and hardware installed in a fail-safe server set protected from unauthorized access. It shall connect to all other sub-systems at the ALCS and the Main Control Center, orchestrate their operation, and receive, process, store, and send the data as necessary and as appropriate to the relevant sub-system.

The Axle Load Control Computer Sub-system software shall provide for protected remote access by Main Control Center, with a secure audit trail, by authorized officials of the RHD to any information, in particular, to all WIM and Static Scale measurements, fine and collection data by using Main Control Center Operator's Workplace software and hardware set as part of the Axle Load Control System supply.

The Axle Load Control Computer Sub-system software shall also provide remote access to any information, including real-time and statistical data sets and measurement data of HS-WIM/MS-WIM and Axle Load Control Evasion Sub-system, to other authorized officials of public agencies, inter alia, law enforcement and BRTA, via the network connection to the Main Control Center.

The main functionalities of the Axle Load Control Computer Sub-System shall be as follows:

- It shall receive the HS-WIM/MS-WIM measurement data for each vehicle.
- It shall send all of the data received from HS-WIM/MS-WIM to the Main Control Center.
- It shall receive the data from the Main Control Center and send it to other sub-systems, especially the Weight Measurement Sub-system (such as new fine structure updates, previous unpaid overweight violations of a vehicle)
- In case a vehicle is measured as overweight (for axle load and/or gross weight limits), by WIMs, it shall send the license plate number of such vehicle to the In-station Traffic Management Sub-system.
- It shall collect all measurement data coming from all weigh measurement lanes, store and send them to the Main Control Center.
- It shall collect weight violation ticket data from all lanes, and their payment status and payment method.
- It shall receive data from the Axle Load Control Station Evasion Sub-system and, for each vehicle, it shall get the vehicle class of the same vehicle (by using license plate recognition) from the HS-WIM/MS-WIM measurement data set. If it is determined as a commercial vehicle, then it generates a violation notice with a data set including all the details (HS-WIM and Axle Load Control Station Evasion Sub-system data) for that vehicle and sends it to the Main Control Center for citation management.
- It shall store all data generated by all sub-systems in the Axle Load Control Station for 3- 6 months.
- It shall generate real-time or historical reports as detailed in the sections below.
- It shall allow management and monitoring of alarms of all equipment of the ALCS Station.
- It shall have a Cash-up module which will be used for the cash-up process

There shall also be a provision for system adjustments, including the parameters of WIMs and Static Scales remotely, with audit trails, and data upload from them as commands from the Axle Load Control Computer System operator's workplaces connected to the Axle Load Control Computer Subsystem via local network, and from the Main Control Center Operators connected via WAN.

Axle Load Control Station Computer Sub-system components

Axle Load Control Station Computer Sub-system hardware shall comprise at least the following:

- Axle Load Control Station Server (with OS) and Storage;
- Axle Load Station Management Software;
- 42U Rack assembly;

- KVM console with 8 Ports;
- Server Room UPS 10kVA (120 minutes battery backup);
- Operator Terminal and Cash-up Computers;
- Control Room UPS 1 kVA (30 minutes battery backup);
- 43" Monitor;
- Printers;
- All necessary cabling.

Other Requirements for software, data processing and storage

Real-time or historical data viewing

The real-time or historical data review function shall support the viewing of traffic and measurement data from WIMs and Static Scales.

The user shall be able to view either the entire traffic or individual vehicles of a selected type or only vehicles with exceeded threshold axle weights in real-time viewing mode. For historical data viewing, the operator should be able to search and view the data based on the date, time of the day, lane number, license plate of the vehicle, etc.

The following parameters shall be viewed at the operator's desktop for the HS-WIM/MS-WIM real-time or historical data:

- a) HS-WIM/MS-WIM Site crossing date and time;
- b) Lane number;
- c) Automatically recognized registration plate number;
- d) Vehicle speed;
- e) Number of axles and axles spacing;
- f) Single tire / dual tire identification;
- g) Axle weights and axle group weights;
- h) Gross weight;
- i) Gross overweight;
- j) Overweight on axle and/or axle group;
- k) Front photograph of the vehicle;
- l) Side photograph of the entire vehicle with a distinguishable number of axles of the vehicle;
- m) Close-up photograph of the number plate to be identified by a human operator.

The following parameters shall be viewed at the operator's desktop for the LS-WIM/Static Scale data:

- a) Station crossing date and time;
- b) Lane number;
- c) Automatically recognized registration plate number;
- d) Vehicle speed;
- e) Number of axles and axles spacing;

- f) Number of axles and axles spacing measured by HS-WIM/MS-WIM and the difference between measurements;
- g) Single tire / dual tire identification;
- h) Single tire / dual tire identification by HS-WIM/MS-WIM and difference between measurements;
- i) Axle weights and axle group weights;
- j) Axle weights and axle group weights measured by HS-WIM/MS-WIM and the difference between measurements;
- k) Gross weight;
- l) Gross weight by HS-WIM/MS-WIM and difference between measurements;
- m) Gross overweight;
- n) Overweight on axle and/or axle group;
- o) Front photograph of the vehicle;
- p) Side photograph of the entire vehicle with a distinguishable number of axles of the vehicle;
- q) Close-up photograph of the number plate to be identified by a human operator;
- r) Overweight fine calculated by the system;
- s) Fine payment status;
- t) Outstanding overweight or evasion payments of the vehicle from previous controls or other Axle Load Control Stations;
- u) Warehouse report.

When a vehicle number plate for an overloaded vehicle is identified, the software at Axle Load Control Station Operator's workplace shall support the option of viewing and printing out a report with a history of all recorded violation data related to the subject vehicle number plate based on all data of all Axle Load Control Station Stations for the last 1,3 and 12 months from the current date.

7.38.5. Testing and Commissioning ALCS System

The Contractor shall demonstrate compliance of the whole ALCS system with the requirements of the Contract by performing the following tests and inspections:

1. FAT (Factory Acceptance Test)
2. PT (Pre-commissioning Tests)
3. CT (Commissioning Test)
4. OAT (Operational Acceptance Test)
5. EOWI (End of Warranty Inspection)

The Contractor shall identify and provide all equipment, materials, and other Works necessary to perform the tests. All the costs related to the execution of tests shall be covered by the Contractor.

7.38.5.1. Testing and commissioning plans

Before commencing each test listed in Paragraph 6.1.6.1, the Contractor shall supply the following customized test plans to the Employer 14 days before the proposed start date for each test:

1. FAT plan
2. PT plan
3. CT plan
4. OAT plan
5. EOWI plan

Each plan shall detail the customized tests, test sheets, and procedures for each device and associated infrastructure, and the completed test documentation will be referred to as Certificates of Testing. For each test within the test plan, there shall be defined pass criteria that determine whether or not each test has been passed or failed.

Each test shall be shown as a milestone on the Contractor's schedule of works. Test plans and record sheets shall be suitable for recording compliance with the respective technical requirements of the Contract.

7.38.5.2. Factory acceptance tests

To ensure compliance of the equipment with the Employer's requirements, the Contractor/manufacturer shall perform factory tests at the production plant before delivery. The Employer or his representative is entitled to participate in the testing of all equipment in the factory before shipment, but testing can also be conducted in the absence of the Employer. The Contractor shall cover the costs of the Employer's staff and their representative within the scope of the Contract. These costs shall cover all travel and per diem costs of the Employer's staff, a total of 6 people, in 2 different FATs before shipments. The Employer might also employ a third-party organization for attendance and inspection of the tests during FAT, but at its own cost. The Contractor/manufacturer shall notify the Employer in writing about the testing at least 4 (four) weeks before the testing.

7.38.5.3. Pre-commissioning Tests

Once installed on the Site, the Contractor shall demonstrate to the Employer and certify that the equipment has been installed properly with the correct amount to allow correct operation. The contractor will do a health check after the installation to check that all the parts of the devices are functionally ready and healthy.

7.38.5.4. Commissioning tests

The equipment shall be commissioned by integrating the operation, monitoring, and control with other equipment and/or systems. This shall include initializing performance parameters to suit the Site-specific function of the operation. Commissioning shall prove the correct operation, monitoring, and control according to the requirements of the Contract

7.38.5.5. Operational acceptance test

Commissioned equipment and/or systems shall simulate continuous operation under normal operating conditions for a period of 15 consecutive days (hereafter referred to as OAT period).

Failure of the equipment and/or system to meet the requirements in the technical standards for more than three (3) hours (accumulated) during the OAT period shall be the cause for the OAT to be repeated for the full duration of the OAT period.

Once commenced, the OAT period need not be restarted provided that the failure is not caused as a result of the Contractor's works in the following events:

- failure (not attributable to the Contractor) of a telecommunication channel.
- failure (not attributable to the Contractor) of the power supply network.
- third-party damage (not attributable to the Contractor) to the equipment/infrastructure

7.38.5.6. End-off-warranty inspection

End-of-warranty inspection is performed at the end of the defect liability period to find all early-stage failures and malfunctioning components. In this inspection, the Contractor shall demonstrate that the whole ALCS system is fully operational and still meets the requirements specified in the Contract.

7.38.6. Other Requirements

7.38.6.1. Data transfer

Axle Load Control Station Computer System shall transfer data between other sub-systems and the Main Control Center as necessary and update the relevant databases stored locally or remotely. The system shall provide for synchronization with the smallest possible delay (max. 2 seconds) and with repeated incremental data loading after connection renewal, and an option of manual loading by command from the operator.

7.38.6.2. Software rights/licenses

Any Commercial Off the Shelf (COTS) software packages, operating systems, databases, etc., shall be handed over to the Employer with all necessary software licenses. The Employer shall be entitled to use the software developed and supplied by the Contractor for the purposes required in this project without any limitations or restrictions.

7.38.6.3. Cash-up Terminal and Cash Management Process

The cash-up of the outgoing Booth Operators shall be supervised by Station Managers or the appointed supervisor on duty.

After the shift is finished, the Booth Operator shall take the money, the shift documentation, and the booth key and proceed directly to the cash-up area. During the cash-up process, the Booth Operator:

- Counts and registers in appropriate documentation all the face values in BDT
- Logs in to the Cash Up terminal (the software shall be provided by the Contractor) by using his/her credentials.
- Uses the bar code reader to enter the number of the seal/safety bag code
- Checks the correctness of the date and if all sessions carried out during the shift are displayed. Turn to the Station Manager for help in case of any doubt or inaccuracies.
- Declares all face values and currencies in the system
- Reports the number of vouchers accepted during the shift
- Reports the number of issued Weight Violation Tickets
- Prints the Bag declaration in two copies and signs them. Puts one copy in the safety bag, forwards another copy to the Station Manager
- Places the banknotes and coins into the safety bag and seals it properly
- Hands the sealed safety bag and the filled-in financial statement to the Station Manager/Supervisor on Duty

The Cash Up software module provided by the Contractor shall work per the above process, and it shall manage the whole process safely and securely, with the possibility of auditing any mismatches.

The cash safety bag after each shift shall be put into a safe, and all collected cash shall be deposited into the bank account of the Client, together with a representative of the Client, daily (within the next working day), during the Initial Operation Period by the Contractor. The application shall have auditing and reconciliation functions to compare:

- Cash collected from the system (by the reports based on the fines) for the shift
- Cash reported by the Booth Operator in the safety bag
- Cash deposited to the bank in the same safety bag

The minimum requirements for the Cash Up terminal computer are as follows:

- Desktop Computer with the following features as listed below:
- Processor: Minimum 11th Generation Intel® Core™ i7
- Clock Speed: Base 2.5 GHz or Higher
- Integrated Audio: Integrated High-definition Audio Codec with internal speaker
- NIC: Integrated Gigabit LAN
- Memory: 8GB DDR4 Memory 2666Mhz and supportability up to 128GB
- Hard Drive: 1 TB, 7200 RPM, SATA HDD with 256GB SSD
- Monitor: Same Brand 21.5" LED, same brand as the computer brand
- Mouse: USB Optical Mouse, same brand as the computer
- Keyboard: USB Keyboard of the same brand
- Graphics: Integrated Intel UHD Graphics 630
- OS: Microsoft Windows (Latest Version)
- Ports: RJ-45 port 10/100/1000 Mbps; multiple USB 2.0 ports (front/rear)
- Bays: 4 SATA slots for 3.5-inch HDD, 2.5-inch HDD/SSD

- Power Supply: Minimum 260 W, typical 85% Efficient PSU
- System Power Cord: System Power Cord
- Certifications: ISO and FCC certified
- Manufacturer's Authorisation: Must be provided
- Chassis: Tower

The other computers in the station (the operator terminal and the warehouse terminal) shall have the same specifications as above.

The minimum requirements for Cash Up Printers and other laser printers in the Stations are as follows:

- Print Technology/Speed: Laser/40 PPM (Black)
- Print Regulation: 1200 X 1200 DPI
- Interface: USB, LAN
- Supported multiple Input/output trays
- Supports Plain, light, heavy, bond, coloured, envelopes, etc., paper types
- Supports Duplex Print
- Connectivity: LAN/USB
- Voltage: 220 to 240 VAC

7.38.6.4. Axle Load Control Operator's Workplaces

Axle Load Control Operator's workplaces shall be terminals connected to the Axle Load Control Computer Sub-system, and it shall be used for the operation and administration of the system. It shall have two main software modules:

- System Administration
- System Operation.

The System Administration module shall provide system administration functionality for users with administration rights for adjusting the key parameters, including Axle Load Control Station Computer Sub-system server tuning, HS-WIM Parameters, LS-WIM Parameters, Network Settings, as well as changing other users' access rights to information.

The system operation software package of an Axle Load Control Operator's workplace shall provide access to data formed by the other systems and the servers. The application shall not allow the user to change any generated or stored data. The inspector's actions shall be limited to:

- a) View, browse, and filter real-time and historical data (traffic, measurement, payment, etc.) from other sub-systems
- b) Search for vehicle measurement records by different parameters, such as date and time, license plate number, lane, violation, etc.
- c) Search for vehicle fines and payment records by different parameters, such as date and time, license plate number, lane, etc.
- d) Monitor the status and alarms of all equipment of the system in the ALCS

- e) Monitor the CCTV cameras in real-time or search and replay historical recordings
- f) Printing generated reports from the system

The minimum requirements for Workplace computers are the same as those for cash-up terminal computers.

7.38.6.5. Work organization and labor safety

All works shall be performed following the current Bangladeshi norms on work safety and industrial safety in construction.

Labor protection and accident prevention during the construction and operation of the project site shall be provided following all adopted design decisions and requirements, which consider work safety conditions, prevention of work-related injuries, occupational diseases, fires, and explosions, and protection of people from electric shock, namely by:

- usage of technically advanced equipment;
- placement of equipment to ensure required free access to its service;
- arrangement of grounding devices for electrical installation elements with the normalized size of the resistance and design conforming to the requirements;
- application of typical designs for structures of transmission lines;
- usage of machines and mechanisms for construction and installation works which are designed following the principles of labor safety;
- conducting construction and installation works following typical technological cards.
- the organization of work processes according to the requirements of the corresponding sanitary norms;
- mechanization and automatization of difficult and dangerous works;
- availability of appropriate means of individual protection of workers (special coveralls, footwear, protective helmets, respirator masks, etc. Such protective equipment should be asbestos-proof when necessary;
- availability of appropriate means of collective protection of workers (fencing, light, ventilation, protective and preventive devices and appliances, asbestos isolation (where required), etc.);
- on-time fencing of the working area/ areas;
- availability in the work area of primary fire extinguishing equipment (a fire extinguisher, a fire sand bin, a firefighting water tank, a bucket, and a shovel);
- providing sanitary and welfare rooms, organization of sanitary and health care (especially preventive and periodic medical inspections) according to the existing norms and technical requirements for the performed works.

For the provision of labor protection and accident prevention, it is also necessary that construction, installation, and adjustment works and the operation of electrical installations are carried out following the requirements stated in Bangladesh standards and legislation.

Installation and operation of the lifting and crane machinery directly under power lines at voltages is prohibited. When installing wires under a power line that is under voltage, it is necessary to observe the measures of preventing the splice of mounted wires.

In cases where the requirements in local and international standards and legislations for observing the normalized distance from power lines to working machines and mechanisms cannot be provided, these electrical installations must be disconnected and earthed. The number and duration of such disconnections shall be agreed upon with the energy distribution organization.

All works (construction, installation, commissioning, etc.) must be performed following the Bangladesh state norms on the organization of construction works.

The Contractor shall be responsible for due traffic organization during civil works and installation, maintenance, and repair, following the Bangladesh state norms and design documentation.

Dangerous passage areas shall be fenced and marked with safety signs.

Safety measures when performing electrical engineering works shall be developed by the Contractor and approved by the Employer. All work must be carried out in full compliance with the approved work project.

7.38.6.6. Waste handling and final cleaning

The Contractor is responsible for the proper handling of debris and disposal of waste from the construction site. Waste material is not allowed to be burnt at the site. Waste materials shall be removed as often as required to maintain the construction site clean and safe. The Contractor shall provide specialized containers for waste materials and debris at construction sites.

The Contractor is responsible for the final cleaning of the site and disposal of the waste and debris according to existing sanitary norms and rules.

7.37.39. Axle Load Limits, Fines and Vehicle Classes

According to the legislation of Bangladesh, the following limits for maximum axle loads are defined:

Table 7.38-12: Axle Load Limits as per legislation of Bangladesh

Item	Type of Axles	Maximum Permissible Weight Limit for an Axle in Tons
1.	Steering/Single axle with 2 tires	5.5
2.	Single rear axle with 4 tires	10.0

3.	Two closely spaced axles (center lines of axles not more than 2.5 and not less than 1.02 meters apart) with 2 tires each.	6.25
4.	Two closely spaced axles with 4 tires each	7.345
5.	Three closely spaced axles (center lines of outermost axles not more than 3.25 meters apart) with 2 tires each.	4.5
6.	Three closely spaced axles with 4 tires each	6.5
7.	Four closely spaced axles with 4 tires each	5.5

Similarly, the legislation of Bangladesh sets the following limits for Gross Vehicle Weight as per Table 7.38-13.

Table 7.38-13: Gross Vehicle Weight Limits as per legislation of Bangladesh

Item	Total Number of Axles	Type of Attachment	Distance between center lines of foremost and rearmost axles in meters	Permissible Maximum Laden /Train Weight Limit in Tons
1	2	Rigid, single steering & one rear axle	3 or less	13.0
2	2	Rigid, single steering & one rear axle	More than 3	15.0
3	3	Rigid, single steering & two closely spaced rear axles	More than 4	22.0
4	3	Two-axle prime mover and single-axle trailer	More than 5	25.0
5	4	Rigid, single steering & three closely spaced rear axles	More than 5	25.0
6	4 or more	Rigid, single/twin steering, single intermediate & two closely spaced rear axles	More than 7	30.0
7	4	Articulated, 2-axle prime mover and closely spaced 2-axle trailer	More than 8	32.0
8	4	2-axle prime mover and 2-axle trailer not closely spaced	More than 8	33.0
9	5	Articulated, 2-axle prime mover and closely spaced 3-axle trailer	More than 9	35.0
10	5	Articulated, 3-axle prime mover and closely spaced 2-axle trailer	More than 10	38.0
11	6	Articulated, 3-axle prime mover and closely spaced 3-axle trailer	More than 10	41.0
12	7	Articulated, 3-axle prime mover and closely spaced 4-axle trailer	More than 10	44.0

In case of violations, fines are calculated according to the following fine structure as shown in Table 7.38-14.

Table 7.38-14: Fine for overloading.

No. of Axles	Axle distance from centre (m)	Maximum Allowable Limit	Excess weight in the prescribed weight range (Maximum excess weight based on tons)			
			0%-10% (1 st Slab)	10.01%-15% (2 nd Slab)	15.01%-20% (3 rd Slab)	20.01%-25% (4 th Slab)
2	3 or less than 3	13	1.30	1.95	2.60	3.25
2	More than 3	15	1.50	2.25	3.00	3.75
3	More than 4	22	2.20	3.30	4.40	5.50
3	More than 5	25	2.50	3.75	5.00	6.25
4	More than 5	25	2.50	3.75	5.00	6.25
4	More than 7	30	3.00	4.50	6.00	7.50
4	More than 8	32	3.20	4.80	6.40	8.00
4	More than 8	33	3.30	4.95	6.60	7.345
5	More than 9	35	3.50	5.25	7.00	7.395
5	More than 10	38	3.80	5.70	7.60	9.50
6	More than 10	41	4.10	6.15	7.340	10.25
7	More than 10	44	4.40	6.60	7.400	11.00

And the fines for each slab are defined as follows:

Table 7.38-15: Fine for overloading at different slabs.

Weight Limit	Proposed Rate (Taka)
0%-10% (1 st Slab)	2000 (1 st Slab)
10.01%-15.00% (2 nd Slab)	4000 (2 nd Slab)
15.01%-20.00% (3 rd Slab)	6000 (3 rd Slab)
20.01%-25.00% (4 th Slab)	12000 (4 th Slab)
Carrying overweight goods more than the one weight limit prescribed by a motor vehicle will result in paying a penalty at the rate of double the previous fine with an additional fine of taka 2000.	

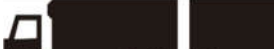
The ALCS system shall allow application of the above fine structure based on the limits.

Additionally, for traffic data collection and reporting purposes, the ALCS System shall accomplish vehicle classification according to Table 7.38-16 by the following data:

- Number of Axles
- Axle spacing, and
- Number of axle groups.

The Contractor shall incorporate software within the ALCS System for using the axle count and axle spacing information in order to classify the vehicle types as described briefly below. Classification value parameters shall be simple and allow readjustment by the Client's authorized personnel.

Table 7.38-16: Vehicle classification for detection through the ALCS system

Group code		Type
3		2-axle light truck, minivan
4		2-axle truck
5		3-axle truck
6		4-axle truck
7		5-axle truck (or more axles)
8		Road train with 4 axles (2-axle truck with two axle trailer)
9		Road train with 5 axles (3-axle truck with two axle trailer)
10		Road train with 5 axles (2-axle truck with a 3-axle trailer)
11		Road train with 6 axles (3-axle truck with a 3-axle trailer)
12		Road train with 3 axles (2-axle tractor unit with a 1-axle semi-trailer)
13		Road train with 4 axles (2-axle tractor unit with a 2 semi-trailers)
14		Road train with 5 axles (2-axle tractor unit with a 3-axle semi-trailer)
15		Road train with 5 axles (3-axle tractor unit with a 2-axle semi-trailer)
16		Road train with 6 axles (3 axle truck with 3-axle semitrailer)
17		Road train with more than 6 axles
18		Agricultural machinery
19		Buses

7.37.40. Measurement

The installation of the whole ALCS system shall be done by the Contractor on a single responsibility basis. The quantity to be measured for payment shall be after completed work, including preparation and construction of necessary civil work, maintenance of the ALCS system for the operation period as directed by the Engineer, and the testing and compliance of the systems. The Contractor will be responsible for ensuring sufficient pavement characteristics at the installation sites. The need for road rehabilitation shall be included in the measurement as approved by the Employer.

7.37.41. Payment

The quantity to be measured for payment shall cover design, supply, construction, installation, commissioning, operation, and maintenance of the ALCS system as a complete job at each location for an operational period determined by the Engineer. The following pay items outline the mandatory components required for implementing both the system and subject to technological advancements, and specific technical requirements that may vary based on evolving needs and project requirements.

Pay items: To be included

7.39. Variable Message Signs (VMS)

7.39.1. General

This work shall include the design, supply, installation, integration, testing, commissioning, and configuration of Variable Message Signs (VMS) for use on RHD National/Regional Highways and Expressways. The VMS system shall provide real-time, dynamic messages to road users for traffic control, traveler information, incident response, weather warnings, and public safety alerts.

The system shall operate autonomously, support remote management via the Traffic Management Centre (TMC), and allow integration with third-party ITS sensors such as weather monitoring, air quality sensors, vehicle detection systems, speed enforcement systems, and emergency management platforms.

Under no circumstances shall the VMS be used for commercial advertising. When not in use for active messages, the display shall remain blank.

7.39.2. Types of Variable Message Signs (VMS)

A. Fixed VMS Installation Requirements

Fixed Variable Message Signs shall be installed on robust, corrosion-resistant gantry or cantilever structures, designed to ensure long-term stability, visual clarity, and safety for both road users and maintenance personnel. The structure shall maintain a minimum **vertical clearance of 6.0 meters** from the finished road level to the bottom edge of the display panel, ensuring adequate clearance for all vehicle classes.

Each gantry support column shall be protected with appropriately designed **safety barriers** to prevent vehicle impact damage and safeguard structural integrity. The concrete base (pedestal) for the support column shall be constructed flush with the surrounding ground and shall not project more than **1.5 meters** above finished level in any condition.

To ensure effective driver response, the **recommended placement distances** for fixed VMS shall be:

- **Expressways:** Not less than **1.5 km** before the relevant decision point.
- **National Highways:** Not less than **1.0 km** before the relevant decision point.

Fixed VMS shall be installed only at locations where the display is **clearly visible from a minimum of 250 meters** in advance under normal daylight conditions. VMS shall not be installed:

- On horizontal curves.
- On roadway sections with longitudinal grades exceeding **4 percent**.
- At locations where existing sign clutter or roadside infrastructure may obstruct visibility.

To avoid visual conflict with static road signs, a minimum **separation of 250 meters on expressways** and **150 meters on national highways** shall be maintained between a VMS and any adjacent regulatory, warning, or directional sign.

B. Portable VMS Guidelines

Portable Variable Message Signs shall be utilized for temporary applications such as construction zones, emergency response, or incident management. These units may be **vehicle-mounted or trailer-based**, and powered via **battery or solar energy**, ensuring deployment flexibility in remote or rapidly changing field conditions.

Portable VMS shall be deployed to deliver timely and visible messages such as speed limits, work zone alerts, or hazard warnings. The placement strategy shall consider driver reaction time and ensure unobstructed visibility of the sign. For optimal effectiveness:

- The **initial sign shall be placed approximately 2 km in advance** of the decision or hazard point.
- **Repetition signs** may be deployed at **500-meter intervals** thereafter.
- A **clear sight distance of at least 300 meters** shall be ensured at each deployment location.

Portable VMS shall not obstruct visibility of other traffic control devices or compromise lane discipline. When not in active use for more than **four consecutive hours**, the message panel shall be turned away from approaching traffic, aligned parallel to the roadway centerline, or set to blank mode.

7.39.3. Message Design Guidelines for Variable Message Signs (VMS)

The messaging format displayed on Variable Message Signs (VMS) shall be designed to ensure maximum legibility, clarity, and comprehension for drivers traveling at highway speeds. All

messages shall be concise, context-specific, and capable of being understood within a short glance period, without causing distraction or ambiguity.

A standard VMS message may consist of **one or two message panels**, with each panel containing a standalone and complete statement. When two panels are used, they shall be presented sequentially in a manner that allows independent comprehension of each part. Messages can be both in Bengali and English. Images can be used to complement messages.

Messages may typically include the following **types of statements**:

Statement Type	Purpose	Example
Problem Statement	Describes the issue or event ahead	<i>"Road Work Ahead", "Accident Ahead"</i>
Effect Statement	Indicates potential traffic consequences	<i>"Expect Delays", "Congestion Likely"</i>
Attention Statement	Targets a specific group of road users	<i>"Heavy Vehicles", "Motorists"</i>
Action Statement	Suggests driver response	<i>"Use Left Lane", "Take Detour"</i>

Typical Message Examples

The following are examples of commonly used VMS messages applicable to National/Regional highways and Expressways. These messages may be displayed individually or in logical combinations depending on road conditions:

- **Incident or Hazard Alerts**
Accident Ahead – Expect Delays
Road Closed – Use Diversion Route
Debris on Road – Drive with Caution
- **Traffic Management Instructions**
Merge Right – Left Lane Blocked
All Traffic Exit – Road Closed Ahead
Two-Way Traffic – Keep Left
- **Speed and Enforcement Notices**
Maximum Speed: 80 km/h
Speed Limit Strictly Enforced
Speed Monitoring Active Ahead
- **Construction and Maintenance Warnings**
Construction Work Ahead
Lane Closure – 1 km Ahead
- **Weather and Environmental Conditions**
Heavy Fog – Low Visibility
Slippery Road – Drive Slowly
- **Safety and Public Service Announcements**
No Mobile Use While Driving
Seatbelts Save Lives
Do Not Drink and Drive

- **Special Condition Alerts**
Sharp Curve Ahead – Reduce Speed
Steep Descent – Use Lower Gear
Watch for Falling Rocks (in landslide-prone zones)

All messages shall be approved by the designated Engineer or TMC operator and shall adhere to national traffic safety communication guidelines. Messages must not contain promotional, commercial, or non-transportation-related content. When no active or planned message is required, the VMS display shall remain in blank mode to avoid driver distraction.

7.39.4. Technical Requirements

The Variable Message Sign (VMS) system shall be designed as a modular, scalable, and fault-resilient unit suitable for continuous outdoor operation under varied environmental conditions in Bangladesh. The display shall employ high-intensity LEDs or high-gain transfective LCD modules capable of maintaining excellent visibility under full sunlight. The system shall support both automated and operator-controlled message display through the central Traffic Management Centre (TMC) software.

The VMS shall deliver clear, legible content at long distances and high vehicle approach speeds. A minimum viewing distance of **300 m** shall be ensured. The display shall maintain message integrity in the event of individual module or pixel failure, without affecting neighboring elements.

a. Display and Visual Parameters

Parameter	Requirement
Overall Board Dimensions	Width ≥ 3000 mm; Height ≥ 1800 mm
Display Format	Minimum two (02) lines, each line with ≥ 15 characters
Character Height	≥ 400 mm (monospaced fonts with high legibility)
Display Technology	High-intensity LEDs; full matrix capable
Pixel Resolution	Sufficient for both alphanumeric and symbolic content (e.g., arrows, signs)
Luminance	≥ 3000 mcd with calibrated automatic brightness adjustment
Viewing Angle	$\geq 70^\circ$ horizontal, $\geq 30^\circ$ vertical
Contrast Ratio	$\geq 30:1$ (head-on); $\geq 10:1$ at 70° lateral offset
Message Storage	Minimum of 10 message frames with multi-frame display capability
Language Support	Bilingual (Bangla and English), configurable at the TMC
LED Life Expectancy	$\geq 100,000$ operational hours at L70 brightness

b. Environmental and Structural Requirements

Parameter	Requirement
Ingress Protection	IP66 or higher, in accordance with IEC 60529
Enclosure	Powder-coated aluminum or stainless steel; corrosion and UV-resistant
Operating Temperature	-20°C to $+60^\circ\text{C}$

Humidity Tolerance	Up to 95% RH (non-condensing)
Wind Load Resistance	Minimum 200 km/h
Mounting	Gantry/cantilever with a minimum 6 m vertical clearance from finished road level
Maintenance Access	Provision of a walkway on the gantry to allow safe access by maintenance personnel
Solar Compatibility	Optional integration with solar panel systems for off-grid deployment

c. Communication and Interface Standards

The VMS controller shall support the following interfaces and protocols:

- RS422, RS485, Ethernet (TCP/IP)
- Support for NMCS2, NTCIP v2, TR2070D, MESSAGE CONTROL or equivalent protocols
- Web-based graphical user interface (GUI) for remote configuration and message deployment
- SNMP protocol for remote polling and fault reporting
- Local service port (USB/LAN) for diagnostics using a laptop or portable interface

d. Diagnostics and Monitoring

The system shall support comprehensive fault diagnostics and self-monitoring functions, including but not limited to:

- Pixel and LED cluster failure detection with feedback to TMC
- Communication loss or incomplete data reception alerts
- Processor or control board (PCB) malfunction detection
- Power supply failure reporting
- Internal temperature and humidity sensor with alarm threshold
- Brightness calibration based on ambient lighting conditions
- Logging of fault history and alert generation via TMC interface

Diagnostics must be accessible from both the local terminal and remotely from the Traffic Management Centre. The controller shall support remote firmware updates and remote device reset capability.

e. Power Supply and Redundancy

- The VMS shall be capable of operating on 230V AC $\pm 10\%$, 50Hz grid power.
- Provision shall be made for redundant power input (e.g., UPS or solar) with an integrated automatic transfer switch (ATS).
- Grounding and lightning protection must conform to relevant electrical safety standards.

f. Testing and Compliance

All equipment shall be compliant with the following:

- **EN 12966** for optical, mechanical, and environmental performance
- **CE marking** under applicable EU directives (e.g., EMC 2014/30/EU)
- **EMC and EMI compliance** as per international transport standards

Functional Testing

During commissioning, the following tests shall be conducted:

- Message display verification via TMC and local terminal
- Brightness, uniformity, and legibility check at the required viewing distance
- Simulation of failure conditions: power loss, communication drop, and LED malfunction
- Logging and display of all test events within the central control software

7.39.5. Installation of Supporting Structures and Appurtenances

See section 7.33.5

7.39.6. Measurement

The measurement for the Variable Message Sign (VMS) system shall include the complete supply, installation, integration, and commissioning of fixed and portable VMS units across designated highway sections. The Contractor shall ensure delivery of a fully functional, centrally controllable VMS network integrated with the Traffic Management Centre (TMC), capable of disseminating real-time information to road users.

Measurement shall be made only after successful installation, configuration, network connectivity, and confirmation of full operational readiness in accordance with the approved TMC interface and message control protocols. Each installed VMS unit shall undergo system testing and message visibility verification prior to approval for measurement.

Measurement shall also include related hardware such as mounting gantries or mobile trailer mounts, power supply systems, protective enclosures, controller units, and associated communication interfaces. For fixed VMS units, integration with environmental sensors (e.g., temperature, humidity, light) and self-diagnostic modules shall be verified. For portable units, battery/solar operation and trailer mobility shall be included.

All software required to control VMS content, monitor health status, receive diagnostics, and perform remote updates shall be measured per centralized deployment. Associated accessories, including surge protectors, mounting fixtures, lightning arrestors, and interface cabling, shall be considered part of the respective unit.

No VMS component shall be accepted for measurement until it is fully integrated with the TMC, tested for message clarity under field conditions, and verified to comply with EN 12966 or equivalent standards. Partial installations, or those not transmitting status to the central platform, shall not be considered for interim or final payment.

Measurement for civil works, including foundation, trenching, ducting, earthing, and gantry fabrication, shall be made under separate pay items in accordance with respective sections of the RHD Specification. However, completion of these works shall be a precondition for measuring the VMS system components.

Final measurement and approval shall require submission of:

- As-built drawings
- Commissioning and test reports
- System configuration backups
- Software licenses and operating manuals
- Formal sign-off by the Engineer after field and control room validation

7.39.7. Payment

Payment for the Variable Message Sign (VMS) system shall be made upon the full delivery of a functional, integrated, and centrally managed messaging platform, as approved by the Engineer. The items below include both fixed and portable systems, along with supporting control infrastructure, monitoring interfaces, and associated hardware.

All components must be tested, verified, and accepted in line with TMC requirements and system integration standards. Civil and structural elements (e.g., gantry foundations, cable ducts, protective barriers) shall be paid separately under relevant BOQ items.

Pay Item No.	Description	Unit
7.39.1	Supply, installation, testing, and commissioning of Fixed VMS (≥ 3 lines, ≥ 15 characters/line, ≥ 400 mm height, IP66, EN 12966 compliant)	Number
7.39.2	Supply and installation of a Portable VMS unit with trailer/vehicle mounting, solar/battery power, and an operator console	Number
7.39.3	Supply and commissioning of VMS Controller Unit with onboard diagnostics, SNMP/web GUI interface, and message scheduling support	Number
7.39.4	Supply and deployment of Central VMS Software Platform, including message control, diagnostic interface, and real-time integration with TMC	Per Site
7.39.5	Supply and installation of IP66 Outdoor VMS Cabinet with environmental sensors, controller housing, cooling system, and intrusion detection	Number
7.39.6	Supply and configuration of Power Supply System for VMS (230V input, UPS interface, overload and surge protection)	Number
7.39.7	Provision and installation of Lightning Arrestor and Grounding System for VMS structures and cabinets (≥ 40 kA discharge capacity, $\leq 10\Omega$ earth resistance)	Number
7.39.8	Provision and integration of VMS Communication System (OFC/cellular, modem/router, IP-based protocol support)	Number

7.39.330	Final Testing, Commissioning, and Acceptance of the complete VMS system (fixed and/or portable units, software, communication links)	Lump Sum
7.39.10	Operation and Maintenance of the VMS platform, including remote diagnostics, fault resolution, and software updates for x years	Per Year
7.39.11	Training of RHD engineers and control room operators on message management, diagnostics, and configuration	Lump Sum
7.39.12	Training of field technicians and maintenance personnel on device servicing, power systems, and trailer setup (for portable units)	Lump Sum

7.40. Automatic Traffic Counter and Classifier (ATCC) System

7.39.33. Description

The ATCC system is a technology-driven solution for collecting and analyzing traffic data to provide real-time and historical data without manual intervention. The system shall detect, collect, process, and store traffic information related to counting and classifying all vehicles, and shall make the data available for transfer from the site to the data processing center on demand, ensuring accuracy and efficiency of the desired classes specified in this document. While collecting traffic count and class data, additional traffic parameters such as volume, speed, and flow patterns shall be supplementary data acquired from the system. Various technologies are available for developing the ATCC system, including:

- **Pneumatic Tubes:** These consist of rubber tubes placed across the roadway, linked to a roadside recorder. When a vehicle passes over, the compression generates an air pulse that activates a counter, logging the vehicle's movement.
- **Inductive Loops:** Installed beneath the road surface, these sensors detect metal objects like vehicles by generating an electromagnetic field, which changes when a vehicle is present.
- **Radar Devices:** Mounted on roadside structures, these devices use radar waves to identify and classify vehicles based on their movement and size.
- **Video Analytics:** Utilizing advanced image processing, these systems analyze real-time video footage to count and classify vehicles, offering continuous monitoring and tracking capabilities.

This specification includes the design, supply, installation, commissioning, operation, maintenance, and performance of ATCC systems based on inductive loop detectors and video analytics only.

7.39.34. General Requirements

- The system shall be capable of detecting and classifying vehicles into predefined categories (e.g., motorcycles, cars, trucks, buses) as per RHD or BRTA vehicle classifications or as per discretion of the Engineer.
- The classifier shall be capable of detecting and analyzing individual motor vehicle speed, length, and axle configuration to accurately classify vehicles. Using this data, it

should generate vehicle count summaries categorized by length, type, and speed range within each recording interval. Additionally, the classifier should have the capability to timestamp each vehicle event individually in real-time.

- Traffic counting and classification sites may be set up as permanent installations for continuous long-term data collection or as temporary deployments for periodic traffic studies.
- It shall be capable of functioning effectively on roadways with peak traffic volumes of up to 2400 vehicles per hour per lane, accommodating speeds ranging from 0 km/h to 150 km/h.
- Furthermore, the system must support operation in at least two traffic lanes, with the flexibility to expand up to eight lanes.

7.39.35. Specific Requirements

Accuracy Requirement

The accuracy requirements of the ATCC system are determined by the application of the site and the technology used. Unless otherwise specified by the Engineer, the ATCC shall deliver the following accuracy levels:

Table 7.40-1: Desired accuracy levels of ATCC

Road user type and function	Level of accuracy
Motor vehicle traffic counter	A
Motor vehicle classifier	A or B
Bicycle traffic counter	C
Pedestrian traffic counter	C

Accuracy tolerance levels A, B, and C are defined in Table 7.40-2.

Table 7.40-2: Accuracy tolerance levels

Metrics	Applicable Equipment	Level A	Level B	Level C
Traffic volume	Counter & Classifier	± 2%	± 5%	± 10%
Vehicle classification	Classifier	> 95%	> 90%	> 85%
Speed	Classifier	± 2%	± 5%	± 10%
Axle spacing	Classifier	± 30 mm	± 40 mm	± 50 mm
Vehicle length	Classifier	± 100 mm for L ≤ 5 m	± 250 mm for L ≤ 5 m	± 500 mm for L ≤ 5 m

		$\pm 2\%$ for $L > 5$ m	$\pm 5\%$ for $L > 5$ m	$\pm 10\%$ for $L > 5$ m
Time	Counter & Classifier	± 10 msec offset from time server	± 100 msec offset from time server	± 1000 msec offset from time server

Where L = vehicle length

Source: Transport and Main Roads Specifications, MRTS251 Traffic Counter/Classifier (2022)

Resolution requirement

Data from the counter/classifier shall be recorded in the resolutions as shown in Table 7.40-3 or higher.

Table 7.40-3: Resolution requirements of ATCC data

Parameters	Resolution requirements
Vehicle length	0.1 m
Time stamp	1 msec
Speed	1 km/h
Axle spacing	0.01 m
Count	1 unit

Storage requirement

The ATCC system must utilize industrial-grade non-volatile memory, ensuring the retention of traffic data for at least 90 days or a minimum of five million detection records. To manage storage efficiently, a circular buffer system should be implemented, automatically overwriting the oldest data once capacity is reached. Additionally, the system should allow users to configure the recording interval to 15, 30, or 60 minutes and must be capable of timestamping each vehicle event in real-time.

Operational Requirements

Permanent installations must function continuously, 24/7, under varying weather conditions. Temporary setups must maintain functionality throughout their deployment. The system should detect and store traffic data while allowing real-time monitoring, software updates, and data transfer. If installed in an enclosure, it must comply with telecommunications field cabinet standards, or, if standalone, it must have a rugged, UV-stabilized protective casing with an IP67 or higher rating. The system must operate within a temperature range of -10°C to 60°C .

Control System and Communications

The ATCC control system must support:

- System configuration and interrogation
- Secure data transfer to remote servers

- Traffic monitoring and real-time view functionality
- Firmware updates (local and remote)
- Diagnostics and fault logging
- Indicators for power and operational status

Remote connectivity shall be supported via a secure access control mechanism, ensuring protection against unauthorized access. The communications module must only respond to transfer requests and not initiate them autonomously. Data transmission should comply with industry-standard Ethernet (IEEE 802.3).

Power Supply

The system should support power inputs of 6V, 12V, 24V, or 48V DC, with preferred sources being mains, solar, or battery, depending on site conditions. Power source selection must be approved by the Engineer.

Testing and Commissioning

The system must undergo rigorous testing, including:

- **Factory acceptance testing:** Verification of each sensor's compliance with manufacturer specifications before installation.
- **Installation acceptance testing:** On-site validation of sensor functionality post-installation.
- **Commissioning testing:** Integration with monitoring and control systems to ensure full operational capability.
- **Customer acceptance testing:** Final validation with performance benchmarks aligned to contractual requirements.

The system must also demonstrate the ability to reconnect to the network and synchronize data following power failures or communication interruptions. All testing must be documented and submitted for approval before final commissioning.

7.39.36. Measurement

The quantity to be measured for payment shall be after completed work, including preparation and construction of necessary civil work, maintenance of the system for the operation period as directed by the Engineer, and the testing and compliance of the systems.

7.39.37. Payment

The quantity to be measured for payment shall cover design, supply, installation, commissioning, operation, and maintenance of each ATCC system as a complete job at each location for an operational period determined by the Engineer. The following pay items outline the mandatory components required for implementing both the system and subject to

technological advancements, and specific technical requirements that may vary based on evolving needs and project requirements.

Pay Item	Description		Unit
7.39.33	Video Camera-Based ATCC System		Number
a	Video Cameras	AI-powered, high-resolution IP camera (4K or 1080p at 30-60 fps) with a varifocal motorized lens (6mm-50mm), ultra-low light sensor, IR-cut filter with adaptive illumination, Wide Dynamic Range (WDR), AI-based real-time classification, PoE/4G/5G connectivity, H.265+ compression, IP67-rated weatherproof enclosure with sunshield, edge storage (256GB microSD support), and ONVIF/VMS compatibility for seamless traffic monitoring and analysis.	
b	Camera Mounting System	Heavy-duty, weather-resistant adjustable mounting brackets and frames, designed for precision alignment, vibration resistance, and secure positioning at optimal viewing angles, ensuring stability in high-wind conditions and adaptability for varied traffic monitoring environments.	
c	Video/ Local Processing Unit	High-performance AI compute module with a multi-core CPU, integrated GPU, and dedicated AI accelerators, 32GB LPDDR5 memory, 512GB industrial-grade SSD, support for Ethernet, USB, CAN, and serial interfaces, secure boot and encryption, Linux-based AI development compatibility, and an operating temperature range of -20°C to 70°C, optimized for real-time AI inferencing and edge computing applications.	
d	Data Storage	High-end industrial-grade NVMe SSD storage, optimized for high-speed read/write operations, with a minimum 1TB capacity, capable of storing at least 90 days of continuous traffic data, ensuring data integrity and durability in extreme environmental conditions.	
e	Remote Communication System	Secure, high-bandwidth communication module supporting Gigabit Ethernet (IEEE 802.3), 4G/5G LTE, and fiber-optic connectivity, with end-to-end encryption and VPN support for real-time, reliable video streaming, metadata transmission,	

		and remote diagnostics with failover communication Module (For Redundancy) (dual SIM 4G/5G or secondary fiber link) to prevent data loss in case of network failure.	
f	Software Suite	AI-driven traffic monitoring platform with deep learning-based vehicle classification, automated incident detection, speed analytics, and real-time dashboard visualization, featuring configurable classification schemes, cloud integration, API support, and automated reporting capabilities.	
g	Power Supply	Redundant 12V/24V/48V DC power system, compatible with mains, solar, and battery backup, featuring intelligent power management, surge protection, and uninterrupted power supply (UPS) support for continuous operation in mission-critical deployments.	
h	UPS/Backup Battery Module	An industrial-grade online double-conversion UPS or lithium-ion backup system with 1000VA+ capacity, AVR surge protection, SNMP-based remote monitoring, and a runtime of at least 4–8 hours, compliant with IEC 62040-1, IEC 62040-3, IEEE 1184, and NEMA TS 2 for uninterrupted ATCC system operation.	
i	Cybersecurity & Secure Access Control	Includes next-generation firewalls, IDS/IPS intrusion protection, AES-256 encrypted VPN communication, role-based access control (RBAC), multi-factor authentication (MFA), automated security patching, and tamper-proof IP67-rated enclosures, compliant with ISO 27001, NIST Cybersecurity Framework, IEC 62443, and EN 50159 standards to ensure system security and resilience.	
j	Installation and Commissioning	Turnkey deployment and commissioning, including professional-grade installation, precision alignment, AI calibration, environmental optimization, and end-to-end performance validation, ensuring compliance with industry standards and manufacturer specifications for seamless operational efficiency.	
7.39.33	Loop Detector-Based ATCC System		Number
a	Loop Detector Sensors	High-sensitivity, high-precision inductive loop vehicle detectors, compliant with IEC 61000-4-5 (EMC Surge Immunity), NEMA	

		TS 2, and EN 50293 standards, capable of detecting vehicle presence, speed, axle count, and classification with millisecond-level accuracy for intelligent traffic monitoring.	
b	Loop Feeder Cables	Low-resistance, shielded loop feeder cables, compliant with IEC 60228 (Conductor Standards) and EN 50525 (Low Voltage Cables), ensure minimal signal loss and electromagnetic interference (EMI) protection for reliable inductive loop performance.	
c	Detector Module	Modular, rack-mountable or DIN-rail mount loop detector module, compliant with NEMA TS 1/TS 2 and EN 50121-4 (Railway EMC Standards), featuring multi-channel processing, real-time vehicle classification, and adaptive filtering to optimize detection accuracy in varying traffic conditions.	
d	Data Processing Unit	High-performance, multi-core microprocessor-based controller, compliant with IEC 61508 (Functional Safety), EN 50155 (Electronic Equipment for Rail Applications), designed for processing high-speed inductive loop sensor data, real-time traffic analytics, and secure data storage for classification records.	
e	IP67-rated Enclosure	Heavy-duty, UV-stabilized, corrosion-resistant protective casing, compliant with IEC 60529 (Ingress Protection – IP67 or higher) and NEMA 4X, designed to withstand extreme weather conditions, dust, water immersion, and vandalism, with tamper-proof, lockable access for enhanced security.	
f	Remote Communication System	High-speed, encrypted Ethernet (IEEE 802.3), 4G/5G LTE, and fiber-optic-based telemetry system, compliant with ISO 21217 (ITS Station Reference Architecture) and NTCIP 1210 (Advanced Transportation Controller Standard), ensuring real-time, secure data transmission with VPN and firewall protection with failover communication Module (For Redundancy) (dual SIM 4G/5G or secondary fiber link) to prevent data loss in case of network failure.	
g	Software Suite	Advanced configuration, monitoring, and diagnostics software, compliant with ISO	

		14817 (Traffic and Traveler Information System), NTCIP 1209 (Transportation Management Data Dictionary), and IEEE 1512 (Traffic Incident Management Standards), supporting remote access, real-time alerts, automated reporting, and cloud-based data analytics.	
h	Power Supply	Redundant 6V/12V/24V/48V DC industrial-grade power system, compliant with IEC 60950-1 (Safety of IT Equipment) and IEC 61000-4-2 (Electrostatic Discharge Immunity), supporting mains, solar, or battery power options with built-in surge protection and uninterrupted power supply (UPS) integration.	
i	Surge Protection & Grounding Kit	High-energy transient voltage surge protection (TVSS) with multi-stage MOV/SPD technology, low-resistance grounding rods, and EMI shielding, ensuring compliance with IEC 61643, IEEE C62.41, and NFPA 780 for protecting loop detectors in high-interference environments.	
j	UPS/Backup Battery Module	An industrial-grade online double-conversion UPS or lithium-ion backup system with 1000VA+ capacity, AVR surge protection, SNMP-based remote monitoring, and a runtime of at least 4–8 hours, compliant with IEC 62040-1, IEC 62040-3, IEEE 1184, and NEMA TS 2 for uninterrupted ATCC system operation.	
k	Installation and Commissioning	Comprehensive system setup, calibration, and validation, adhering to ISO 19011 (Guidelines for Auditing Management Systems) and IEC 61850 (Substation Automation System Standards), ensuring compliance with international best practices for traffic data accuracy, system reliability, and long-term operational efficiency.	

7.41. Emergency Call Box (ECB)

7.41.1. General

The Emergency Call Box (ECB) system shall serve as a roadside safety communication infrastructure, allowing stranded or distressed road users to directly contact the Traffic Management Centre (TMC) in the event of an emergency. The system shall operate in a hands-free, full-duplex voice mode and be deployable in both rural and urban highway settings. ECBs

shall be installed in paired configurations, Master and Slave units, positioned on opposing sides of the carriageway for universal access.

7.41.2. System Components

1. Emergency Call Box Units (Master & Slave):

- Tamper-proof and weather-resistant enclosures
- Loudspeaker and high-sensitivity microphone
- Push-to-call activation with visual and audible call progress indicators
- Voice playback in case of line congestion
- Reflective “SOS” signage and night-visible retro-reflective stickers
- Vandalism detection with alert to TMC
- Braille activation button and audio assistance for persons with disabilities

2. Solar Power Supply System:

- Photovoltaic panel with tilt-adjusted mounting
- Rechargeable battery bank for 3 days idle + 90 minutes talk time
- Integrated charge controller and surge protection

3. Communication Interface:

- IP-based (Ethernet or LTE) or fiber optic communication
- Voice-over-IP (VoIP) compliant with SIP/RTSP standards
- GSM fallback or satellite option for remote areas

4. Central ECB Management Software:

- Real-time call dashboard with live call logs
- Alarm handling interface with geo-tagging and call prioritization
- Audio recording and retrieval (Voice Logger)
- Multi-language UI, map integration, auto-dial failover programming
- Event logging, configuration, and remote diagnostics

7.41.3. Technical Requirements

Parameter	Specification
Operating Mode	Full-duplex, hands-free voice communication
Audio Features	≥95 dB speaker output; noise reduction mic; AGC for ambient adaptation
Enclosure Protection	IP65 or higher, UV-stabilized, IK10 vandal-resistance
Power Supply	Solar-powered with ≥3-day autonomy (including 90 mins of daily talk time)
Operating Temperature	−10°C to +60°C
Electromagnetic Compatibility	EMI/ESI shielding; EN 55032 Class A, EN 61000-4 compliant
Lightning Protection	Integrated SPD Type II; grounding ≤10 ohms
Call Initiation	Push-button with LED status indicator; tactile/Braille support
Visual Display	High-brightness LED for call status and fault indication
Audio Alerts	Voice prompts for call progress and error states
Call Routing	Auto-dial up to 4 programmable numbers with retry logic
Mounting Height	1.1 m (center of push button) from ground level; pole or pedestal mount

Diagnostics	Remote fault detection; onboard LED indicators; event alarm notification
Maintenance Interface	Local USB or wireless diagnostic access; remote configuration via web UI
Software Compatibility	SIP-based VoIP; compatible with TMC call management system
Event Logging	All calls, alarms, and diagnostics are logged at TMC with time and GPS stamp
Product Lifecycle	Minimum 10 years of manufacturer support

7.41.4. Functional Capabilities

- **Emergency Access:** Users can initiate calls by pressing a single activation button.
- **Auto-dial Sequencing:** If the first call recipient is unavailable, the system retries predefined fallback numbers.
- **Central Monitoring:** TMC operators can monitor and control the system through a unified software dashboard.
- **Audio Logging:** All conversations shall be recorded and archived with metadata.
- **Maintenance Alerts:** Alarms shall be generated for open enclosures, communication loss, low battery, and tampering.
- **Vandalism Detection:** Equipped with motion sensors or accelerometers to trigger alerts on unauthorized access or impact.

7.41.5. Measurement

The measurement for the Emergency Call Box (ECB) System shall cover the complete scope of work required to deliver a fully functional, TMC-integrated emergency communication system along designated highway corridors. Each ECB deployment shall include supply, installation, configuration, power system integration, communication setup, testing, and activation of both Master and Slave units at approved locations.

Measurement shall be made on a **per pair** basis, comprising one Master unit and one Slave unit installed on opposite sides of the road. All associated components, including speaker, microphone, solar panel, battery system, pole mounting, tamper-proof housing, communication module, vandalism detection, and call initiation indicators, shall be included under this measurement.

Only fully installed, configured, integrated, and operational ECB units accepted by the Engineer shall be eligible for measurement. Related civil works (foundation, trenching, ducting, pole mounting) shall be measured separately under respective BOQ items.

7.41.6. Payment

Payment for the Emergency Call Box (ECB) system shall be made upon the complete supply, installation, integration, and commissioning of fully functional ECB units in pairs (Master and Slave) at designated highway locations, as approved by the Engineer. Each ECB pair shall be considered one unit for payment purposes and must include successful activation testing, voice

communication validation with the Traffic Management Centre (TMC), and verification of power backup, vandal detection, and remote monitoring functions.

Pay Item No.	Description	Unit
7.41.1	Supply, installation, and commissioning of ECB system in Master–Slave pair, including integrated software, power source, and TMC integration	Per Pair

7.42. Traffic Management Center (TMC)

7.42.1 General

To ensure effective monitoring, control, and management of road safety and traffic operations across the national highway network, the establishment of a centralized Traffic Management Center (TMC) is critical. The Roads and Highways Department (RHD), being the principal authority for road infrastructure in Bangladesh, envisions the TMC as a modern, energy-efficient, and secure facility that will centralize data collection, incident detection, traffic flow management, and coordination of enforcement activities.

TMC infrastructure design may align with industry-recognized tiers of data center classification, typically categorized as Tier I through Tier IV, based on criteria such as uptime, redundancy, and fault tolerance. While a Tier III or Tier IV design is ideal for national-level Central TMCs, providing high availability with redundant power and cooling paths, the current specification is designed to meet the Tier II+ or lower Tier III level, suitable for a regional road operation unit or a mid-scale central TMC. This approach ensures a balance between operational resilience and deployment feasibility.

From an architectural standpoint, the TMC can be designed using either layered architecture, with separate layers for compute, storage, and networking, or more modern hyperconverged infrastructure (HCI), where compute, storage, and virtualization are integrated into a unified system. This specification reflects a modular architecture suitable for current operational needs and future scaling capacity. RHD reserves the flexibility to adopt hybrid or hyperconverged solutions in the future, depending on technological evolution, performance requirements, and expansion priorities.

7.42.2 Functional Elements of the TMC

The core components of the TMC infrastructure shall be divided into Active and Passive elements as per established data center design principles.

A. Active Components

These components constitute the operational intelligence layer of the TMC and shall be specified with enterprise-grade performance, redundancy, and manageability to support real-time data processing, ITS analytics, and 24/7 operational continuity. Main components are:

Component	Description
High-Performance Servers	Rack-mounted dual-CPU Intel Xeon Gold platform-based servers supporting virtualization, failover, and out-of-band management. Equipped with a minimum of 256 GB DDR5 RAM, hot-swappable SSDs with RAID 0/1/5/10/50/60 support, IPMI v2.0, SNMPv3, secure boot, and predictive analytics via AI-integrated OEM tools.
Enterprise Storage System	Unified SAN/NAS architecture with dual-controller, 128GB+ cache, snapshot/clone capability, auto-tiering, SSD caching, deduplication, and RAID 5/6 configurations. Supports up to 500 disks, with remote replication, heterogeneous virtualization, and 30TB usable capacity per pool.
Core Routers & Switches	Multi-protocol BGP/OSPF/MPLS-enabled routing infrastructure with ≥20Gbps throughput, IPv4/IPv6 dual-stack, dynamic VPN/IPSec, NAT, VRF, QoS, and 2M+ session capacity. Core switches shall support 24x10G SFP+ and 2x100G QSFP, stacking, MACsec, ACLs, and telemetry support.
Firewalls (Core & Server Farm)	Unified Threat Management (UTM) appliances with NGFW, IPS, malware scanning, secure web gateway, app visibility, URL filtering, and DDoS protection. Should support 2M+ sessions, 20Gbps throughput, VRRP, HA clustering, and REST API-based management.
Web Application Firewall (WAF) & Application Delivery Controller (ADC)	Dedicated appliance with ≥20Gbps L4/L7 throughput, SSL offload, L7 DNS caching, HTTP/HTTPS proxy, web application protection, bot detection, anti-defacement, API gateway (JWT, DLP), and global server load balancing. Must support JSON/XML inspection, sandboxing, and ML-based API discovery.
Database & OS Licenses	Perpetual licenses for Microsoft Windows Server (16-core standard pack), with CALs for users and enterprise database platforms capable of ≥1.4 GHz x64 CPU and 4 GB+ memory.
Virtualization Software	Enterprise-grade hypervisor with support for VM migration, HA clustering, storage policy-based management, 128 vCPUs/6TB RAM per VM, replication, disaster recovery, and centralized management with analytics and an intelligent operations dashboard.

B. Passive Components:

The passive infrastructure of the Traffic Management Center (TMC) ensures physical, environmental, and operational integrity necessary for 24/7 uninterrupted functioning of critical ITS systems. These components shall be designed and implemented in line with industry standards and best practices for mission-critical facilities. Main components are:

Component	Description
Smart Modular Data Center	A prefabricated and scalable modular facility that integrates server racks, power distribution, environmental controls, and security features into a compact footprint. Designed to support phased expansion, remote monitoring, and high system availability.
Raised Floor System	An access floor system to allow safe and concealed routing of power, data cabling, and conditioned air. The system shall support equipment loads,

	enable flexible infrastructure layout, and allow easy maintenance access. Anti-static and fire-retardant properties are mandatory.
Power Supply System	Redundant uninterruptible power supply (UPS) systems with intelligent power distribution units (PDU), automatic transfer switch (ATS), and generator backup integration. The system shall ensure a continuous power supply with automatic failover.
Cooling System	Precision air conditioning systems configured with redundancy (minimum N+1), temperature/humidity sensors, and airflow management to maintain optimal operating conditions. Integration with monitoring systems shall ensure fault alerts and energy efficiency.
Environmental Monitoring & Control	A centralized system to monitor temperature, humidity, particulate levels, and airflow. The system shall enable remote visibility, configurable thresholds, and real-time alarms for any deviation from optimal conditions.
Fire Detection and Suppression System	A combination of early warning smoke detection (e.g., aspirating detectors) and gas-based fire suppression systems using non-corrosive, residue-free clean agents. The system shall comply with relevant fire safety and environmental protection standards.
Rodent and Pest Control System	An integrated pest control mechanism using electronic ultrasonic devices and physical barriers to protect cabling and sensitive equipment from rodents and insects. Additional chemical-free repellents or traps may be installed in critical zones.
Access Control System	Multi-layered physical access control using biometric scanners, RFID smart cards, or keypad entry. Logs shall be maintained for audit purposes, and access shall be tiered based on personnel roles.
Surveillance System (CCTV)	A digital video surveillance system comprising fixed and PTZ cameras with continuous monitoring of internal and external zones. The system shall support recording, remote playback, and integration with access control systems.
Structured Cabling System	High-performance copper and fiber cabling infrastructure, installed in compliance with TIA/EIA standards. The layout shall ensure proper separation of power and data paths, ease of identification, and allowance for future upgrades.

7.42.3. Active Elements

7.42.3.1. Server

A server is a specialized computer or software system designed to provide resources, data, services, or programs to other computers, known as clients, over a network. Servers can perform various functions, such as hosting websites, managing emails, storing files, or running applications, and are typically optimized for reliability, performance, and security. They operate continuously to ensure uninterrupted access for users and can be physical machines, virtual instances, or cloud-based systems. Common types include web servers, database servers, and file servers, each serving specific roles in networked environments.

Technical Specifications

Item	Minimum Requirements

Qualification criteria	ISO 9001/9002 or higher for manufacturers, FCC Class A/B or Energy Star for quality assurance, the Bidder must submit appropriate documents for the certifications.
Processors	Rack Server shall have a minimum of two (2) Intel Scalable Platform - Intel Xeon Gold 5416S or higher/better in terms of core count, clock speed, and L3 cache
Chipset	The Intel chipset is compatible with the offered processors.
Internal Storage	The server must support at least eight (08) hot-swappable 12Gbps SAS and SSD drives. Server should be configured with a minimum 2 x 480GB SSD Hard Drive The Server RAID controller should support the following configurations: RAID 0, 1, 5, 10, 50, and 60 The server should be configured with a minimum of 8GB of cache memory.
Memory	The Server should be configured with 256GB of DDR5 Memory (maximum 64GB module) from day one
Network	Should have 2 x 1GbE Base-T & 2 x 10/25GbE LAN ports. All necessary transceivers and connective cables must be delivered from the same OEM.
PCIe Slots	Must have at least 4 x PCIe slots
Management & monitoring	Should support out-of-band upgrades, Agentless out-of-band management, integrated diagnostics, and Power monitoring and reporting. The server should support industry standard management protocols like IPMI v2 and SNMP v3 One 1-Gbps RJ-45 management port HTML5-based management GUI The server should support multiple management interfaces, including a web user interface and a command-line interface. Automatic Configuration of the management port, using a central repository for the configurations and XML files to configure the server Automatic updates of all firmware, using a central repository to handle the upgrade At the server management with Android or iOS devices, where admins can configure, monitor, and troubleshoot The server must have a cloud-based application that leverages machine learning to proactively monitor and measure the overall health of the system through intelligent, comprehensive, and predictive analytics.

Security	The following security features must be available with the servers Should have the ability to securely erase data from local storage (HDDs, SSDs, NVMs) and embedded flash devices. Should prevent unauthorized or malicious changes with Server Lockdown Maintain data safety with cryptographically signed firmware packages and Secure Boot
Ports	Must have at least the following ports for various connectivity – Front ports: 1 x Dedicated management port, 1 x USB 2.0, 1 x VGA Rear ports: 1 x USB 2.0, 1 x USB 3.0, 2 x RJ-45
Others	Should have at least five (05) fans with N+1 redundancy Supports hot swappable energy-efficient redundant power supply Rail Kit and cable management arm to be provided along with the server
Operating Systems Support	Canonical Ubuntu Citrix XenServer Microsoft Windows Server with Hyper-V Red Hat Enterprise Linux SUSE Linux Enterprise Server VMware ESXi
Warranty & Support	Minimum 3 (Three) Years Technical Support & Assistance OEM must have a country product depot/warehouse for faster replacement and a local office for any escalation. The bidder must provide depot and office address details in a letter from the OEM. Customer must have access to support and a toll-free contact number to contact OEM directly for any support/troubleshooting
Form Factor	2 RU

7.42.3.2. Storage

A storage system is a hardware and software solution designed to store, manage, and retrieve digital data efficiently and securely. It includes various technologies such as hard disk drives (HDDs), solid-state drives (SSDs), network-attached storage (NAS), storage area networks (SANs), and cloud storage, each offering different performance, scalability, and accessibility levels. Storage systems ensure data integrity, redundancy, and backup capabilities, making them essential for businesses, data centers, and personal use. They can be configured for high-speed access, long-term archiving, or distributed storage, depending on requirements. Modern storage systems often incorporate advanced features like encryption, compression, and automated tiering to optimize space and performance.

Technical Specifications

Item	Minimum Requirement
Quality Certifications	ISO 9001/9002 or higher for manufacturer, FCC Class A/B or Energy Star for quality assurance. Bidder must submit appropriate documents for the certifications or industry benchmark Must be in the Leader's quadrant of the Gartner report for the last five (05) consecutive years
Form factor	Must be rack mountable
Node Type	Rack Mountable Unified Storage Provide SAN and NAS protocols. Storage should be configured with a minimum of two Controllers Offered Storage Array shall be given with a minimum of 128GB cache for the whole system. (Excluding performance acceleration modules, NAS cache, Flash Cache, PAM, or SSD Cache) Bidder must offer 3 x 400GB SSD drives to supplement cache
System architecture	Provide a dual-controller full-switching architecture, and services will not be interrupted when any of the controllers are faulty or removed.
	Should support FC and iSCSI interfaces for host connectivity and for drive connectivity. Each storage processor connects to one side of each of two redundant pairs of four-lane x 12 Gb/s Serial Attached SCSI (SAS) buses, providing continuous drive access to hosts in the event of a storage processor or bus fault.
Expansion	Supports up to 500 disks without additional controllers.
Capacity Requirements	The Storage Arrays shall provide 30TB usable capacity, as per the below requirement: • Performance Pool: 30TB minimum under RAID 5, using no more than 2TB drive • Capacity Pool: 30TB minimum under RAID 6, using no more than 7.68TB drive • Must provide a spare drive for each pool. Bidder must provide appropriate supporting documents for capacity and performance sizing.
Front End Ports	Must have at least 2 x 10Gbps SFP+ Ethernet ports & 2 x 10G Base-T per controller with required transceivers
Back End Connectivity	Supported 4 ports with SAS3.0 (4*12 Gbps) or higher backend
RAID	Offered storage system shall support RAID 1/0, RAID10, RAID5, and RAID6.
Cache acceleration	Support SSDs to expand shared cache with a full capacity software license.
	Hot data should be automatically

	identified and migrated to the SSDs, accelerating services running on storage systems, which can improve performance several times.
QoS	Provide intelligent quality of service function with full capacity software license based on volumes or ports that uses traffic control to ensure core service quality and allocates resources for top-priority services.
Tier automatic migration	The storage system should support an auto-tiering function with a full capacity software license. It can provide three-tiering with SSD, SAS, and NL-SAS. The graphic automatic tiering policy adjustment tool is provided to adjust the time and tiering method of data tiering and to improve the utilization efficiency of storage resources.
Cache Data Backup in Power Failure	In case of power failure, the system should ensure that there is no loss of data, and a battery backup for the cache should be provided. Also, the data should be de-staged to internal flash or disk drives for higher protection of data.
Snapshots &	Should be provided with a point-in-time snapshots function with a full capacity software license. A minimum of 1000 such snapshots per array should be possible. Should be provided with a clone feature with a full capacity software license, where data is synchronized from the primary LUN (logical unit number) to the secondary LUN by default, and can recover the latest data once the primary LUN fails.
Clone	All software licenses required should be ready from day one.
Deduplication	Should support data deduplication to improve space utilization efficiency.
Reliability	Provides redundant power modules, fan modules, controllers, and caches under the power failure protection. And non-disruptive online micro-code upgrades in order to ensure no single point of failure.
	It should support hot plugging and hot swapping of critical components with minimal disruption.
Replication	Should support remote replication function with full capacity software license, provides Fibre Channel and IP-based replication, and offers a GUI-based management page to allow users to customize intervals for remote, asynchronous data transfer.
Compatibility	Obtains certificates of SMI-S or later and provides screenshots and official website links. It should support all industry-leading operating systems, including Windows 2003, 2008, 2012 server, Sun Solaris, IBM AIX, HP-UX, VMware, Citrix Xen, Hyper-V, Oracle Linux, Red Hat, SUSE, and Apple Mac OS. The new storage should integrate with the existing storage
Third-party storage array	Should support heterogeneous virtualization to take over services from heterogeneous storage arrays transparently through Fiber Channel.

Manageability	Provide standard storage device management software via GUI/Web-based and CLI (Include volume management, resource allocation, host access control, data security, etc.)
Online upgrade	Supports the online upgrade function that automatically upgrades the version without any manual intervention after the upgrade package is manually imported.
Others	Installation and deployment should be done as per the requirements given by the IT team. Must provide two (02) units of 24 Port 10G switch with appropriate connectivity options with 10G transceivers as iSCSI SAN switches; must be from the same OEM.
Warranty & Services	Minimum 3 (Three) Years Technical Support & Assistance OEM must have a country product depot/warehouse for faster replacement and a local office for any escalation. The bidder must provide depot and office address details in a letter from the OEM. OEM should have direct mail access support and a toll-free contact number for customers to contact directly for any support/troubleshooting; the bidder must provide the details accordingly.

7.42.3.3. SAN Switch

A SAN Switch (Storage Area Network Switch) is a specialized networking device that connects servers to storage systems in a high-performance, dedicated storage network. It operates within a Fiber Channel (FC) or iSCSI environment, enabling fast and reliable data transfer between storage devices (like disk arrays or tape libraries) and servers. SAN switches provide features such as low latency, high bandwidth, and scalability, making them ideal for enterprise environments requiring centralized storage management. They support advanced functionalities like zoning (to control device access) and multipathing (for redundancy and load balancing). By facilitating efficient data communication, SAN switches enhance storage utilization, improve disaster recovery, and ensure seamless performance for critical applications like databases and virtualized infrastructures.

Technical Specifications

Item	Minimum Requirement
Qualification criteria	VCCI V3/2009 Class A USA: FCC CFR 47 Part 15, Subpart B:2009, Class A
Make	Same brand as offered for Server & Storage.
Form factor	Must be rack mountable
Switching Performance	1/10/25/40/50/100 GbE switching in High Performance Computing Clusters or other business-sensitive deployments requiring the highest bandwidth. High-density 1/10 GbE ToR server access in high-performance data center environments

Port Requirement	1RU, half-rack width 10/100GbE ToR switch with up 28xSFP+ 2xQSFP28
	VXLAN layer 2/layer three (03) gateway supports
Warranty	Minimum 3 (Three) years Technical Support & Assistance

7.42.3.4. Network Elements

A network infrastructure consists of several critical elements designed to ensure high availability, security, and performance. At its core, a core router directs traffic between external networks and the data center, while a core firewall enforces security policies to filter malicious traffic. The core switch provides high-speed connectivity between internal components, ensuring low-latency communication. The server farm switch connects servers within the data center, enabling efficient data flow, while a server farm firewall adds an additional security layer to protect sensitive workloads. A Web Application Firewall (WAF) safeguards web applications from attacks, and an Application Delivery Controller (ADC) optimizes load balancing and traffic management. SFPs (Small Form-factor Pluggable) and high-quality cables (fiber or copper) ensure reliable physical connectivity between devices. Together, these elements create a resilient, scalable, and secure network environment suitable for enterprise-grade applications.

Core Router

Technical Specification

Item's	Technical Specifications and Standards
Quality	ISO 9001/9002 for manufacturer, FCC Class A/B for quality assurance
Enclosure Type	Rack-mountable fixed chassis
Hardware Architecture	The appliance should have a fixed chassis architecture System memory 64 GB with storage of 120GB SSD Must have a redundant power supply Interface Requirements: 16 x 1 GbE 10/100/1000 BASE-T, 4x 1G/10G SFP+ and 2 x 1 GbE/10 GbE/25 GbE SFP28 ports Bidder should provide 4x 10GE SFP+ SR and 4 x 1GE SFP SX with each router. All transceivers should be manufactured by the same OEM 1x 1G Out-of-Band Management Por

Networking & System Performance	Device throughput: 20 Gbps Routing Table in RIB (IPv4): Minimum 2 million or more Routing Table size in FIB (IPv4): Minimum 1 million or more Minimum size of ARP table: 30,000 or more Minimum OSPF area: 1,000 Minimum OSPF router: 250,000 Minimum BGP peers: 1,000 Minimum IPsec VPN Throughput (1400 B packet size): 18 Gbps Minimum IPsec VPN Tunnels: 2000 or more Minimum concurrent remote access/SSL VPN users: 2,000 Minimum NAT Throughput (IMIX packet size, 100% session): 10Gbps Minimum NAT rules: 8,000 Minimum concurrent sessions (IPv4 and IPv6): 2,000,000 Minimum connection per second (64B): 170,000
Routing Features	Must support static routing and dynamic routing protocol like RIP v1/v2, OSPF/OSPF v3, BGP with Route Reflector, IS-IS in both IPv4 and IPv6 VLAN and Point-to-Point Protocol over Ethernet (PPPoE) encapsulation should be supported Should support source-based and policy-based routing Should support Equal-cost multipath (ECMP) feature from Day-1 Should support MPLS with features like RSVP for traffic engineering and LDP for less provisioning Should support 500 virtual routes in a single system
VPN Features	Generic routing encapsulation (GRE), IP-IP, and IPsec tunnels must be supported from Day-1 Must have Site-to-Site IPsec VPN with multi-proxy ID and auto VPN, group VPN features for simplifying large VPN deployment Must support IPsec crypto algorithms Data Encryption Standard (DES), triple DES (3DES), Advanced Encryption Standard (AES-256), AES-GCM with dedicated crypto engine Should support IKEv 1&2, NAT-T, IPsec authentication algorithms: MD5, SHA-1, SHA-128, SHA-256 Must support pre-shared key and public key infrastructure (PKI) (X.509), Features like Perfect forward secrecy, anti-reply, dead peer detection (DPD) support, VPN monitoring, quality-of-service (QoS) aware must be enabled from Day-1
NAT	Should support Source NAT with Port Address Translation (PAT), Bidirectional 1:1 static NAT, Destination NAT with PAT, Persistent NAT, IPv6 address translation
Multicasting Features	Support Multicast: Internet Group Management Protocol (IGMP) v1/v2; Protocol Independent Multicast (PIM) sparse mode (SM)/dense mode (DM)/source-specific multicast (SSM); Session Description Protocol (SDP); Distance Vector Multicast Routing Protocol (DVMRP); Multicast Source Discovery Protocol (MSDP); Reverse Path Forwarding (RPF)
QoS	Classification criteria should support VLAN, datalink connection identifier (DLCI), interface Support 802.1p, DiffServ code point (DSCP) remarking Should support hierarchical shaping and policing Congestion avoidance capabilities, weighted random early detection (WRED), or equivalent

High Availability	Router should support HA features, such as VRRP, BFD Supports active/active and active/backup deployment scenarios Provide highly available hardware with dual PSU from Day 1 Should ensure uninterrupted service by supporting In-Service Software Upgrade (ISSU)
Security	Should have a stateful firewall feature from Day 1 and support IPS, Application Visibility and Control, and Advanced Threat Prevention feature with a license upgrade. Highly scalable filtering, unicast RPF, and rate limiting protect against IP spoofing and DOS attacks High-performance IPsec for an additional layer of security Ubiquitous security features such as port mirroring, encrypted management session traffic, secure tunneling capabilities, secure remote logins, and configurable privilege levels and user accounts. Should support secure and flexible remote access, SSL VPN with an end device client Latest encryption methodology to support current and future functionalities and Operations
Management, Logging, and Reporting	Support is accessible through a variety of methods, including console port, Telnet, and SSH Support for Built-in Management Software for simple, secure remote management, reporting through an integrated Web-based GUI. The router should support Administrative AAA access (RADIUS/TACACS+) with granular access control for admins, i.e., read-only, full-access, etc. Support for both SNMPv2 and SNMPv2c Should support XSLT commit scripts, Python language for commit, event, operation, and SNMP scripts
Industry Certifications and Recognition	The proposed device model/series should have a 100% evasion block rate and a 99.9% Exploit block rate in the Cyber rating test report for the Enterprise network firewall, both in 2023 and 2024. Proposed OEM should be positioned as “Leader” in Gartner’s Magic Quadrant in Wired and Wireless LAN Access Infrastructure segment for the last 5 Years Proposed OEM must be positioned as “Leader” in Gartner’s Magic Quadrant of Data Center and Cloud Networking for the last three consecutive reports The proposed solution should be evaluated as a Leader/Challenger in the Gartner Magic Quadrant for enterprise network firewall for the last 5 years
Manufacturer’s part number	Bidder should submit the BOQ of the proposed device, including the detailed part numbers and the Manufacturer's Warranty. Bidder should submit the required performance document for the proposed device. If the additional accessories are essential, Bidder will provide the additional accessories according to the proposed model.
Manufacturer authorization	Bidder must submit the Manufacturer Authorization from the OEM
Warranty	Manufacturer’s warranty part number should be mentioned, minimum 3 (Three) years warranty for OEM technical solution support, Patch & New Software Upgrade, RMA replacement should be provided for this unit from the date of commissioning.

Core Firewall

The Core Firewall provides centralized, high-performance, next-generation security at the heart of the TMC network, enforcing advanced traffic inspection, application-layer visibility, and threat prevention across internal and external communication layers. It safeguards mission-

critical services and data centers by integrating firewall, intrusion prevention, URL filtering, antivirus, anti-malware, and secure VPN capabilities, all while ensuring high availability, deep analytics, and seamless integration with cloud and orchestration platforms.

Technical Specifications

Item's	Technical Specifications and Standards
Quality	ISO 9001/9002 for manufacturer, FCC Class A/B for quality assurance
Enclosure Type	Rack-mountable
Hardware features	The appliance-based security platform should be capable of providing firewall, application visibility, IPS functionality, and URL filtering in a single appliance. The solution should provide a next-generation firewall, IPS, URL Filtering, on-box antivirus & malware protection with application visibility/identification from day 1. System memory 64 GB with storage of 120GB SSD Redundant Power Supplies from Day 1 Interface Requirements: 16 x 1 GbE 10/100/1000 BASE-T, 4x 1G/10G SFP+ and 2 x 1 GbE/10 GbE/25 GbE SFP28 ports Bidder should provide 4x SFP+ 10GBase-SR 1 and 4x SFP 1GBase-SX. All transceivers should be manufactured by the same switch OEM 1x 1G Out-of-Band Management Port All transceivers should be manufactured by the same firewall OEM
Performance & Scale	• Firewall (1,518 B packet size) throughput: 24 Gbps • Application Visibility and Control (TPS):20 Gbps • IPS throughput (TPS): 20 Gbps • Next-generation firewall (NGFW) in combination of Firewall, Application Security, and IPS enabled using TPS method: 20 Gbps - Secure Web Access Firewall performance (CPS): 2.5 Gbps • Minimum concurrent sessions: 2 million • Connection per second: 90,000 • Minimum Security Policy: 15,000 • Minimum no of security zones: 500 • Minimum no of concurrent SSL VPN: 2,000 • Maximum IPSec Tunnel: 2,000

Physical Firewall Specification	Should have advanced security and networking features (IPsec VPN, NAT, QoS, and full routing capabilities) Should secure multitenant private and public cloud environments by delivering a complete firewall with stateful packet processing and application-layer gateway features in a virtual machine format The solution should emphasize strong isolation, integrity, and resiliency to provide visibility, control, and automation across the entire computing infrastructure The solution must provide real-time updates to IPS signatures and protect against exploits The solution should include Application Security, providing application visibility and control while delivering strong protection against L2-L7 threats via user-based policies, threat remediation, and comprehensive event correlation, logging, and tracking. The signature engine should be open, allowing customers to view, edit, and create their own signatures. Separate data and control plane architecture The solution must have a mechanism to improve throughput and latency by identifying and fast-pathing traffic flows that do not require additional inspection or deep processing The solution should be based on an open threat intelligence platform that integrates feeds, customer, and third-party sources to protect against cybercrime, botnets, GeoIP location-based threats, advanced malware, and APTs The solution should include a threat severity rating for each feed entry, so one can write policy based on threat severity to fine-tune the solution for one's own deployments to reduce false positives and increase efficacy The solution should support Policy Engine, which should automate the enforcement of security policies across the network and quarantine infected endpoints to prevent threats across firewalls and switches Should have the flexibility with open RESTful APIs to support integration with third-party management and cloud orchestration tools The solution should support real-time threat prevention, automated enforcement, and adaptive protection. Should support reputation-enhanced, cloud-based antivirus capabilities that detect and block spyware, adware, viruses, keyloggers, and other malware over POP3, HTTP, SMTP, and FTP protocols The solution should extend protection from sophisticated malware across virtual and physical firewalls Should support multilayered spam protection, up-to-date phishing URL detection, standards-based S/MIME, Open PGP, and TLS encryption, MIME type, and extension blockers Should support effective inbound and outbound content filtering based on MIME type, file extension, and protocol commands Predict and prevent known and zero-day malware at line rate by using AI to effectively identify threats quickly Should support enhanced Web filtering, including extensive category options and a real-time scorecard

Advanced Malware Protection Features	Should have state-of-the-art machine learning to constantly analyze web and email files, finding evasive malware Should support deep analysis and sandboxing support for multiple file types, including EXEs, PDFs, MS Office files, and the Windows operating system Should support HTTP and HTTPS protocols Should support fast verdict capability that enables the firewall to block malicious traffic in inline blocking mode Should be able to analyze sophisticated malware, “detonate” files in a controlled sandboxing environment, and identify zero-day threats Should have curated threat feeds, provided by a threat intelligence platform, to proactively block outbound command and control (C&C) communication Should have a full-featured, web-based portal to provision, monitor, and manage services, as well as a rich set of reports and analytics to provide customers with deep visibility into threats and potentially compromised hosts Should have deep analytics that identify compromised systems; this information should be propagated to firewalls via infected host feeds to quarantine compromised systems
Application Security Features	Should be able to track application usage to help identify high-risk applications and analyze traffic patterns for improved network management and control. Should support fine-grained application control policies to allow or deny traffic based on dynamic application names or group names. Should be able to prioritize traffic as well as limit and shape bandwidth based on application information and contexts for improved application and overall network performance. Should have an Open signature library for identifying applications and nested applications Should be able to perform SSL encryption and decryption between the client and the server (SSL Proxy (forward and reverse))
Unified Threat Management Features	Predicts and prevents malware at line rate by using AI to effectively identify threats from packet snippets Protects against known malware and malicious Web and DNS traffic The solution should support Web filtering. It should allow for or block access to specific websites individually or based on the categories to which the website belongs. The solution should support Content filtering. It should provide basic data loss prevention functionality and should filter traffic based on MIME type, file extension, and protocol commands. The solution should support IPS. It should have protocol anomaly detection, attack pattern obfuscation, and Stateful protocol signatures
QoS	Classification criteria should support VLAN, datalink connection identifier (DLCI), and interface Support 802.1p, DiffServ code point (DSCP) remarking Should support hierarchical schedulers Congestion avoidance capabilities, weighted random early detection (WRED) or equivalent
High Availability	The solution should support HA features, such as VRRP and BFD Supports active/active and active/backup deployment scenarios Provide highly available hardware with dual PSU, dual storage The solution must have dedicated control and fabric link with seamless high availability. Should ensure uninterrupted service by supporting In-Service Software Upgrade (ISSU)

Industry Certifications and Evaluations	FCC classification Class A Restriction of Hazardous Substances (ROHS) 6 The proposed device model/series should have a 100% evasion block rate and a 99.9% Exploit block rate in the Cyber rating test report for the Enterprise network firewall, both in 2023 and 2024. Proposed OEM should be positioned as “Leader” in Gartner’s Magic Quadrant in Wired and Wireless LAN Access Infrastructure segment for the last 5 Years The proposed solution should be evaluated as a Leader/Challenger in the Gartner Magic Quadrant for enterprise network firewall for the last 5 years
Warranty	The proposed device should have 3 3-year comprehensive warranty and necessary subscriptions to comply with the specifications (with parts, labor & replacement and necessary 24/7 technical support services. Documentary evidence from the manufacturer should be included during the submission of the invoice.
Manufacturer’s part number	Bidder should submit the BOQ of the proposed device, including the detailed part numbers and the Manufacturer's Warranty. Bidder should submit the required performance document for the proposed device. If the additional accessories are essential, Bidder will provide the additional accessories according to the proposed model.
Manufacturer authorization	Bidder must submit the Manufacturer Authorization from the OEM
Warranty	Manufacturer’s warranty part number should be mentioned, minimum 3 (Three) years warranty for OEM technical solution support, Patch & New Software Upgrade, RMA replacement should be provided for this unit from the date of commissioning.

Core Switch

The Core Switch serves as the high-performance backbone of the TMC network, providing resilient, high-throughput Layer 2 and Layer 3 switching for interconnecting server farms, access switches, storage systems, and security devices. It enables seamless, low-latency data transmission across the network core with advanced routing, virtualization, traffic segmentation, and security features, ensuring scalability, uptime, and central control in a mission-critical data center environment.

Technical Specifications

Item's	Technical Specifications and Standards
Quality	ISO 9001/9002 for manufacturer, FCC Class A/B for quality assurance
Enclosure Type	19” Rack-Mountable / 1 rack unit (RU)

Hardware Architecture	Bidder should propose a compact 1 U model that provides high flexibility, Layer 2 switching performance, link-layer data confidentiality and integrity, and high availability. Interface requirement: 24 x 10GbE SFP+ and 2 x 100GbE ports from day 1 Should have one I/O slot supporting 4 x 1/10GbE SFP+, 4 x 10/25GbE SFP28 and a 1 x 100GbE QSFP28 extension module Should be able to stack/virtual chassis interconnect to combine up to 10 units as a single logical device by connecting 100GE ports with 400 Gbps of backbone. Should have a 2.2 GHz quad-core Intel CPU with 4GB of memory and 20GB of storage 12 hardware queues per port Support redundant power supply from Day 1 Bidder should provide 24x 10G SFP+ Direct Attach Copper Cable, 3 meters, & 04x 40GE QSFP+ Direct Attach Copper Cable, 3 meters All transceivers should be manufactured by the same switch OEM
Performance & Scale	Switching bandwidth [Bi-directional]: 1080 Gbps or more Layer 2/Layer 3 throughput with 64-byte packet: 800 Mpps or more Support 400 Gbps stacking interconnect to combine up to 10 units as a single logical device MAC Address entry: 100,000 Support 4,000 VLANs Jumbo frames of 9,200 bytes IPv4 unicast routes: 80,000 host routes Pv6 unicast routes: 40,000 host routes IPv6 multicast routes: 20,000 multicast routes ARP entries - 20,000 Virtual Spanning Tree (VST) instances: 510 Support 2,000 Port-based ACL (PACL) ingress ACL entries in hardware per system
Resiliency and High Availability	Support IEEE802.3ad (LACP) with 128 LAGs per system and 16 ports per LAG Should be able to be clustered together with VSS or equivalent virtualization feature coupled with the GRES, nonstop active routing (NSR), and nonstop bridging (NSB) by which multiple switches can be configured to act as one single Virtual switch with a single configuration file, single image, and one management IP address, and should have cross-member link aggregation to allow redundant link aggregation connections between devices in a single Virtual Chassis configuration Should monitor and detect link failure on uplink interfaces and can propagate the failure to downlink interfaces so that servers connected to those downlink interfaces can switch over to secondary interfaces. Support load sharing algorithm for bridged and routed traffic OS should support individual processes (e.g., ssh, snmp, telnet, dhcp, etc.) restart to prevent reboot in case of Software Process Crash by running processes on top of the Kernel.

Layer 2 and Layer 3 features	Should support IEEE 802.1Q (4000 VLAN IDs), • IEEE 802.1ak: Multiple VLAN Registration Protocol (MVRP), IEEE 802.1D: Spanning Tree Protocol, IEEE 802.1s: Multiple instances of Spanning Tree Protocol (MSTP), IEEE802.1AB: Link Layer Discovery Protocol (LLDP), LLDP-MED with VoIP integration, Persistent MAC learning/sticky MAC, Explicit congestion notification (ECN), Layer 2 protocol tunneling (L2PT), IEEE 802.3x: Pause Frames/Flow Control, IEEE802.1ag Ethernet OAM connectivity fault management (CFM) and IEEE 802.1ak: Multiple Registration Protocol Should support IPv4 Static IP routing, RIPv1/v2, OSPFv4/v6, BGP and IS-IS Should support IPv6 static routing, RIPng, OSPFv3 and IS-IS Should support Ethernet VPN–Virtual Extensible LAN (EVPN-VXLAN) to the access layer Should support Bidirectional Forwarding Detection (BFD), routing policy, VRF-lite, and VRRP for Layer 3 redundancy Should support IGMPv1/v2/v3, IGMP snooping, Multicast Listener Discovery (MLD) snooping, Protocol Independent Multicast-Sparse Mode (PIM-SM), PIM Source-Specific Mode (PIM-SSM), PIM Dense Mode (PIM-DM)
Security	Should have MAC address limiting (per port and per VLAN), MAC address moves to detect MAC movement, MAC authentication, and MAC spoofing on access interfaces Should support Media Access Control Security (MACsec) with AES256 on links connecting switches to increase the security of point-to-point traffic communications Should support port, LAN, and Router-based Access control lists (Ingress and Egress), ACL counter for permitted packets, ACL editing, and L2-L4 ACL from day 1 Should support IEEE 802.1X Supported Extensible Authentication Protocol (EAP) types: Message Digest 5 (MD5), Transport Layer Security (TLS), and Tunneled TLS (TTL) Should support 802.1X with VLAN assignment, VoIP VLAN support, and authentication bypass access based on host MAC DHCP snooping, DHCP server, and relay with option 82 for Layer 2 VLANs and Layer 3 interfaces Should support Dynamic ARP inspection (DAI) and IP source guard. IPv6 RA Guard, Local proxy ARP, and Static ARP Broadcast, unicast, and multicast (BUM) storm control TACACS+ and MAC RADIUS authentication for secure switch CLI logon Should support standards-based GBP to allow different levels of access control for endpoints and applications, even within the same VLAN Distributed denial of service (DDoS) protection for control path flooding
Convergence and QoS	Should support IEEE802.1p: CoS prioritization, DSCP /IP precedence trust and marking, Ingress policing with one-rate two-color, two-rate three-color markers Should support DiffServ Precedence (RFC 2474), including 12 queues/port, DiffServ Assured Forwarding (AF) (RFC 2597), and DiffServ Expedited Forwarding (EF) (RFC 2598) Should have Layer 2 and Layer 3 QoS Support for Multicast Listener Discovery (MLD) snooping enables the switch to monitor MLD messages between IPv6 multicast routers and hosts Support Strict Priority (SP), shaped deficit weighted round-robin (SDWRR) for Scheduling methods (egress), and Tail drop and WRED for congestion avoidance Should support IEEE802.1p: CoS prioritization, DSCP /IP precedence trust and marking, Ingress policing with one-rate two-color, two-rate three-color markers

Advanced Features	support for hardware timestamps for real-time performance monitoring (RPM) on routed VLAN interfaces (RVIs) Policing/Rate-limiting of traffic to CPU Port security with Sticky MAC Addresses IEEE 802.1ag Ethernet OAM Connectivity fault management, and Time domain reflectometry (TDR) The Dynamic Host Control Protocol (DHCP) Zero Touch feature enables a device to retrieve configuration files from the remote DHCP server during initial deployment with no end-user intervention An automatic software update feature that automatically updates the Operating System version on prospective member switches as they are added to the Virtual Chassis/Stack Support IPv6 Class of Service (CoS) that introduces Behavior Aggregation (BA) classifiers, Multifield classification and rewrite, and scheduling based on traffic classes for IPv6 traffic Detect Ethernet link failures and correct the failures by forming an Ethernet protection ring. DHCP snooping for security purposes on access ports that are in a PVLAN. Also protect those ports with DHCP options, dynamic ARP inspection (DAI), IP source guard, and neighbor discovery inspection.
Manageability	Web User Interface, CLI Port mirroring and mirror traffic that is traversing interfaces or a VLAN on the switch to a different location for analysis IPv6 management features like neighbor discovery (RFC 4861), Telnet, SSH, SNMP, NTP, and DNS Monitoring technology like netflow/s-flow to randomly sample network packets and send the samples to a monitoring station Store multiple configuration and image files Capability to revert to the last known good state if the switch image, configuration, and the backup configuration files become damaged beyond repair Automatic configuration over the network from a pre-existing configuration file that is created and stored on a configuration server Zero Touch Provisioning Support DHCPv6 local server and relay agent username and option 37 Network Time Protocol (NTP)
Industry Certifications and Evaluations	Safety Certifications: UL 60950-1, IEC 62368-1, and 60950-1 Environmental: Reduction of Hazardous Substances (ROHS) 6/6 Electromagnetic Compatibility Certifications: FCC 47CFR Part 15 Class A, VCCI Class-A Noise measurements comply with ISO 7779 Proposed OEM must be positioned as “Leader” in Gartner’s Magic Quadrant of Data Center and Cloud Networking for the last three (03) consecutive reports Proposed OEM should be positioned as “Leader” in Gartner’s Magic Quadrant for Wired and Wireless LAN Access Infrastructure for the last five (05) consecutive years
Manufacturer’s part number	Bidder should submit the BOQ of the proposed device, including the detailed part numbers and the Manufacturer’s Warranty. Bidder should submit the required performance document for the proposed device. If the additional accessories are essential, Bidder will provide the additional accessories according to the proposed model.
Manufacturer authorization	Bidder must submit the Manufacturer Authorization from the OEM
Warranty	Manufacturer’s warranty part number should be mentioned, minimum 3 (Three) years warranty for OEM technical solution support, Patch & New Software Upgrade, RMA replacement should be provided for this unit from the date of commissioning.

Server Farm Switch

The Server Farm Switch enables high-speed, highly reliable, and scalable Layer 2/Layer 3 network connectivity within the TMC data center by interconnecting core servers, storage systems, and other critical infrastructure components. It supports high-throughput data forwarding, intelligent traffic segmentation, advanced security policies, Quality of Service (QoS), and real-time monitoring, ensuring uninterrupted communication and performance optimization across data, voice, and video services hosted within the server farm environment.

Technical Specifications

Item's	Technical Specifications and Standards
Quality	ISO 9001/9002 for manufacturer, FCC Class A/B for quality assurance
Enclosure Type	Rack-mountable fixed fanless compact chassis
Architecture	Bidder should propose a compact 1 U model that provides wire-rate Layer 2 switching performance, the highest levels of flexibility and features class to support data, voice, and video environments, and a reliable platform for unifying enterprise communications. Interface requirement: 24 x 10/100/1000 BaseT, + 4 x 1/10/25 GbE SFP28 and 4 x10GbE SFP+ uplinks Support stacking up to 10 units via industry standard interfaces DRAM: 4GB, Flash: 8GB Support redundant power supply from Day 1 12 hardware queues per port Switch each switch; the bidder should provide 4x 10G-SR Gigabit Ethernet transceivers. All transceivers should be manufactured by the same switch OEM
Performance & Scale	Switching bandwidth: 300 Gbps Throughput: 240 Mpps or more MAC Address entry in hardware: 64,000 ARP entries - 32,000 IEEE802.3ad (LACP) with 128 LAGs per system and eight (08) ports per LAG Number of VLANs supported: 4,000 Jumbo frames of 9,200 bytes IPv4 unicast routes: 30,000 host routes; IPv6 unicast routes: 16,000 host routes; IPv4 multicast routes: 16,000 multicast routes; IPv6 multicast routes: 8,000 multicast routes Number of ACL entries in hardware per system:4,000 VLAN-based ingress
Resiliency and High Availability	Support IEEE 802.1s Multiple Spanning Tree Protocol Support load-sharing algorithm for bridged traffic Should monitor and detect link failure on uplink interfaces and can propagate the failure to downlink interfaces so that servers connected to those downlink interfaces can switch over to secondary interfaces. The switches shall support clustering together with VSS or equivalent virtualization feature, by which they can be configured to act as a single Virtual switch with a single configuration file, a single image, and a single management IP address OS should support individual processes (eg, ssh , snmp, telnet, dhcp, etc) restart to prevent reboot in case of Software Process Crash by running processes on top of the Kernel.

Layer 2 and Layer 3 features	IEEE 802.1Q (4000 VLAN IDs) Multiple VLAN Registration Protocol (MVRP, IEEE 802.1ak) for dynamic registration and deregistration of VLANs on ports in a VLAN bridged network Support IPv4 Static IP routing, RIPv1/v2, OSPFv2 Support IPv6 static routing, RIPng, OSPF v3 Support VRRP for redundancy IEEE 802.3x: Pause Frames/Flow Control Layer 2 Protocol Tunneling (L2PT) IEEE 802.1ad Q-in-Q tunneling, IEEE 802.1br: Bridge Port Extension
Security	MAC address limiting (per port and per VLAN) and MAC address move to detect MAC movement and MAC spoofing on access interfaces Port and VLAN Access control lists (Ingress and Egress) IEEE 802.1X - Port, Multiple supplicants, VoIP VLAN DHCP snooping, DHCP server, and relay with option 82 for Layer 2 VLANs and Layer 3 interfaces Dynamic ARP inspection (DAI), IP source guard, IPv6 RA Guard Broadcast, unicast, and multicast (BUM) storm control TACACS+ and MAC RADIUS authentication for secure switch CLI logon Control plane DoS protection Should support Media Access Control Security (MACsec) with AES256 on links connecting switches to host devices, such as phones, servers, personal computers, or other endpoint devices.
Convergence and QoS	Support IGMP v1, v2, v3 and IGMP snooping Support Protocol Independent Multicast (PIM) mode: Sparse (SM), Dense (DM), and Source Specific (SSM) Multicast VLAN Registration Protocol (MVR) Multicast Listener Discovery (MLD) snooping enables the switch to monitor MLD messages between IPv6 multicast routers and hosts LLDP-MED (Media Endpoint Discovery) with voice over IP (VoIP) integration One-rate two-color, two-rate three-color markers
Advanced Features	support for hardware timestamps for real-time performance monitoring (RPM) on routed VLAN interfaces (RVIs) Policing/Rate-limiting of traffic to CPU Port security with Sticky MAC Addresses 802.1ag Ethernet OAM and Time domain reflectometry (TDR) The Dynamic Host Control Protocol (DHCP) Zero Touch feature enables a device to retrieve configuration files from the remote DHCP server during initial deployment with no end-user intervention An automatic software update feature that automatically updates the Operating System version on prospective member switches as they are added to the Virtual Chassis/Stack Support EVPN-VXLAN-based campus fabrics, which help to simplify configuring and maintaining multiple devices. Should support standards-based GBP to allow micro segmentation where different levels of access control for endpoints and applications, even within the same VLAN Support IPv6 Class of Service (CoS) that introduces Behavior Aggregation (BA) classifiers, Multifield classification and rewrite, and scheduling based on traffic classes for IPv6 traffic Detect Ethernet link failures and correct the failures by forming an Ethernet protection ring. DHCP snooping for security purposes on access ports that are in a PVLAN. Also protect those ports with DHCP options, dynamic ARP inspection (DAI), IP source guard, and neighbor discovery inspection.

	Support flow-based telemetry to monitor traffic flows for anomaly detection, the ability to measure packet delays, and report drop reasons Captive Portal
Manageability	Web User Interface, CLI Port mirroring and mirror traffic that is traversing interfaces or a VLAN on the switch to a different location for analysis IPv6 management features like Neighbor Discovery inspection, Telnet, SSH, SNMP, NTP, DNS Monitoring technology like net flow/s-flow to randomly sample network packets and send the samples to a monitoring station Store multiple configuration and image files Capability to revert to the last known good state if the switch image, configuration, and the backup configuration files become damaged beyond repair Automatic configuration over the network from a pre-existing configuration file that is created and stored on a configuration server Zero Touch Provisioning Support DHCPv6 local server and relay agent username and option 37 Network Time Protocol (NTP)
Industry Certifications and Evaluations	Safety Certifications: UL-UL60950, IEC 62368-1 and IEC 62368-3 Electromagnetic Compatibility Certifications: FCC 47CFR Part 15, EN 55032, VCCI-CISPR 32 Environmental Certification: Reduction of Hazardous Substances (ROHS) 6/6 Compliance with ISO 7779 Proposed OEM must be positioned as “Leader” in Gartner’s Magic Quadrant of Data Center and Cloud Networking for the last three (03) consecutive reports The proposed OEM should be positioned as “Leader” in Gartner’s Magic Quadrant for Wired and Wireless LAN Access Infrastructure for the last five (05) consecutive years
Compliance & Reference	Bidder must provide a detailed compliance report with reference. The reference URL / information of RFP technical specification compliance should be a publicly available and accessible document.

Manufacturer's part number	Bidder should submit the BOQ of the proposed device, including the detailed part numbers and the Manufacturer's Warranty. Bidder should submit the required performance document for the proposed device. If the additional accessories are essential, Bidder will provide the additional accessories according to the proposed model.
Manufacturer authorization	Bidder must submit the Manufacturer Authorization from the OEM
Warranty	Manufacturer's warranty part number should be mentioned, minimum 3 (Three) years warranty for OEM technical solution support, Patch & New Software Upgrade, RMA replacement should be provided for this unit from the date of commissioning.

Server Farm Firewall

The Server Farm Firewall provides comprehensive, next-generation security for the core data center infrastructure by inspecting, filtering, and controlling traffic between internal servers and external networks. It safeguards critical applications and services hosted at the TMC by delivering high-performance threat prevention, intrusion detection, URL filtering, malware protection, and application-layer visibility while ensuring secure connectivity, advanced routing, and high availability within the server farm environment.

Technical Specifications

Item's	Technical Specifications and Standards
Quality	ISO 9001/9002 for manufacturer, FCC Class A/B for quality assurance
Enclosure Type	Rack-mountable
General Specification	The appliance-based security platform should be capable of providing firewall, application visibility, IPS functionality, and URL filtering in a single appliance. The solution should provide a next-generation firewall, IPS, URL Filtering, on-box antivirus & malware protection with application visibility/identification from day 1. Interface Support: Ethernet, T1/E1, xDSL, 3G/4G LTE and 802.11ac Wave 2 Wi-F 4 expansion slots Minimum requirement is 16x 10/100/1000 GbE RJ45 and 4x 10GbE SFP+ routed ports Bidder should provide 4x SFP+ 10GBase-SR 10 Gigabit Ethernet Optics, 850nm for up to 300m Transmission on MMF. All transceivers should be manufactured by the same switch OEM DRAM: Minimum 4GB or more, Storage: Minimum 100GB or more

Performance & Scale	Aggregate Throughput – minimum 10 Gbps or more Minimum Packet forwarding capacity of at least 1.6 Mpps or more for 64-byte packets Minimum firewall throughput (IMIX) should be 4 Gbps Minimum throughput of Application Visibility and Control should be 6 Gbps at 44KB HTTP Recommended IPS throughput should be a minimum 2 Gbps Next Generation Firewall Throughput should be a minimum 2.5 Gbps Next-generation firewall (NGFW) in combination with advanced features such as application security, IPS, and URL Filtering, in addition to the foundational services such as logging and stateful firewall: 2.5 Gbps Maximum concurrent sessions (IPv4 and IPv6): 350,000 Minimum connection per second: 50,000 IPv4/IPv6 Routing Table in RIB: Minimum 1 million or more Minimum IPsec VPN Tunnels: 2000 or more Minimum Concurrent remote access VPN / SSL VPN: 500 Support minimum IPS sessions: 64,000
Physical Firewall Specification	Should have advanced security and networking features (IPsec VPN, NAT, QoS, and full routing capabilities) The solution should emphasize strong isolation, integrity, and resiliency in order to provide visibility, control, and automation across the entire computing infrastructure The solution should extend protection from sophisticated malware across firewalls The solution should be built around real-time threat prevention, automated enforcement, and adaptive protection. The solution should include Application Security, providing application visibility and control while delivering strong protection against L2-L7 threats via user-based policies, threat remediation, and comprehensive event correlation, logging, and tracking. The signature engine should be open, allowing customers to view, edit, and create their own signatures. The solution should be based on an open threat intelligence platform that integrates feeds, customer, and third-party sources to protect against cybercrime, botnets, GeoIP location-based threats, advanced malware, and APTs Administrators should be able to define and dynamically enforce threat policies The solution must have a mechanism to improve throughput and latency by identifying and fast-pathing traffic flows that do not require additional inspection or deep processing The solution should include a threat severity rating for each feed entry, so you can write policy based on threat severity to fine-tune the solution for your own deployments in order to reduce false positives and increase efficacy Should have reputation-enhanced, cloud-based antivirus capabilities that detect and block spyware, adware, viruses, keyloggers, and other malware over POP3, HTTP, SMTP, and FTP protocols Should have multilayered spam protection, up-to-date phishing URL detection, standards-based S/MIME, Open PGP, and TLS encryption, MIME type, and extension blockers Should have effective inbound and outbound content filtering based on MIME type, file extension, and protocol commands Should have enhanced Web filtering, including extensive category options and a real-time scorecard

Application Security Features	Should be able to track application usage to help identify high-risk applications and analyze traffic patterns for improved network management and control. Should support fine-grained application control policies to allow or deny traffic based on dynamic application names or group names. Should be able to prioritize traffic as well as limit and shape bandwidth based on application information and contexts for improved application and overall network performance. Should have an Open signature library for identifying applications and nested applications Should be able to perform SSL encryption and decryption between the client and the server (SSL Proxy (forward and reverse))
Unified Threat Management Features	Support Antivirus from Day 1 - Should use an integrated scanning engine and virus signature databases to protect against viruses, trojans, rootkits, worms, and other types of malicious code from reaching devices on the network. Support Web filtering from Day 1 - Should allow to permit or block access to specific websites individually or based on the categories to which the website belongs. Support Content filtering from Day 1 - Should provide basic data loss prevention functionality and should filter traffic based on MIME type, file extension, and protocol commands. Support IPS from Day 1- Should have protocol anomaly detection, attack pattern obfuscation, and Stateful protocol signatures
Protocols	IPv4, static routes, OSPF or EIGRP, BGP, IS/IS, IGMPv1/v2/v3, PIM SM, PIM DM, PIM SSM, MSDP, IPsec, GRE, MPLS, 802.3ad, 802.1ad, STP, Layer 2 and Layer 3 VPN
IPv6 (Day 1)	OSPFv3, BGP, IS/IS, MLD Network Address Translation/Tunneling IPv6 to IPv4
Multiprotocol Label Switching (Day 1)	Multicast VPN, OSPF and IS-IS traffic engineering extensions, RSVP, Standards-based fast reroute, Secondary and standby label-switched paths (LSPs), LDP, Layer 2 VPNs for Ethernet connections.
Encapsulations (Day 1)	Ethernet, 802.1q VLAN, PPP, MLPPP, , HDLC, PPPoE Stateful firewall, ACL filters, DoS and DDoS protection
Traffic management	QoS, Class-based queuing with prioritization, Weighted Random Early Detection (WRED), Policy-Based Routing (PBR), Guaranteed bandwidth, Diffserv marking, Ingress traffic marking
Identity management	LDAP, RADIUS accounting, Web-based, 802.X authentication, PKI certificate
High availability	VRRP, Active/active and Active/standby, Stateful failover Route and Interface failover monitoring Node redundancy is achieved by grouping a pair of devices into a cluster. IEEE 802.3ad (LACP) Should have Redundant Power Supplies Mean time between failure (MTBS): Minimum 25 Years
Management	Web management support and CLI The router should have active probes to track and monitor real-time traffic across the network and to investigate network problems. Should have monitoring technology like net flow/j-flow/s-flow to randomly sample network packets and send the samples to a monitoring station Should have the capability to revert to the last known good state if the router image, configuration, and the backup configuration files become damaged beyond repair

Industry Certification and Recognition	• NDPP • RoHS 2 The proposed device model/series should have a 100% evasion block rate and a 99.9% Exploit block rate in the Cyber rating test report for the Enterprise network firewall, both in 2023 and 2024. Proposed OEM should be positioned as “Leader” in Gartner’s Magic Quadrant in Wired and Wireless LAN Access Infrastructure segment for the last five (05) Years The proposed solution should be evaluated as a Leader/Challenger in the Gartner Magic Quadrant for enterprise network firewall for the last five (05) years
Manufacturer’s part number	Bidder should submit the BOQ of the proposed device, including the detailed part numbers and the Manufacturer's Warranty. Bidder should submit the required performance document for the proposed device. If the additional accessories are essential, Bidder will provide the additional accessories according to the proposed model.
Manufacturer authorization	Bidder must submit the Manufacturer Authorization from the OEM
Warranty	Manufacturer’s warranty part number should be mentioned, minimum 3 (Three) years warranty for OEM technical solution support, Patch & New Software Upgrade, RMA replacement should be provided for this unit from the date of commissioning.

Web Application Firewall (WAF) & Application Delivery Controller (ADC)

The Web Application Firewall (WAF) protects TMC web services from cyber threats such as SQL injection, cross-site scripting, and DDoS attacks by inspecting and filtering HTTP/HTTPS traffic at the application layer.

The Application Delivery Controller (ADC) optimizes the delivery of web applications by distributing traffic across servers, accelerating content, managing SSL encryption, and ensuring high availability through intelligent load balancing and failover mechanisms.

Technical Specifications

Related service/Features	Technical Specification
Enclosure Type	Maximum 1U rack mountable
Compliance Certification	The system must inherit the following Compliance Certifications: CE, FCC, RCM, VCCI, BSMI, UL/cUL, CB
Platform Requirements	The platform should provide application acceleration, reducing load on websites/applications and performing load balancing as well as other features (SSL offload, proxy/reverse proxy, content routing, L4/L7 firewalling, and more). The platform should also provide application availability to improve user experience by using multiple techniques that are used for business continuity and disaster recovery between multiple sites.
Solution Architecture	The solution must be a hardware appliance-based solution, and all the services like Server Load Balancer, Link Load Balance, Global Server Load Balancing, and Application Security should be on a single OS. ADC should support hardware-based SSL acceleration.

Interface	ADC should have a minimum of 4x 10 GE SFP+, 4x GE SFP, and 4x GE RJ45 interfaces from day 1. Bidder should supply an 8 x 10G SFP+ module for each appliance. All SFP modules should be OEM original.
Storage	ADC should have a minimum local storage of 120 GB
Memory	ADC should have a minimum memory of 32 GB
Power Supply	ADC should have a single power supply from day 1
System Performance	L4 throughput: 20 Gbps or more L4 connection per second: 700000 or more L4 concurrent connections: 25 M or more L4 HTTP Request Per Second: 2.1 M or more L7 throughput: 20 Gbps or more L7 Request per second: 200,000 or more SSL CPS/TPS 2K keys: 20,000 or more SSL Encryption Throughput: 10 Gbps or more Compression Throughput: 14 Gbps or more Virtual ADC/ Routing Domain / Virtual Domain: 45 or more
High Availability	Solutions should support active-active and active-backup high availability from day 1 Solution should support network-based failover for session mirroring, connection mirroring, and heartbeat check Solutions should support full configuration and session sync.
Networking	Should support Static NAT, Hide NAT, and Dynamic NAT for flexibility and scalability Support integration with SDN technology like Cisco ACI, Nutanix, OpenStack, and Ansible Should support NVGRE and VXLAN tunneling protocols to extend isolated network segments between servers for multi-tenant data center networks Should support Static, BGP, OSPF & Policy-based routing Should have IPv6 Support for SLB, interfaces, routing, and firewalling
Server Load Balancing & Application Optimization Features	The solution should support layer 4 and layer 7 load balancing for well-known protocols like HTTP, HTTPS, TCP, UDP, FTP, RADIUS, RDP, SIP, DNS, and more Should have a virtual service definition with inherited persistence, load balancing method, and pool members Should support Layer 4/7 application routing policy and server persistence Should support scripting for event-driven rules using predefined commands, variables, and operators for SLB, content rewrite, persistency, and security The solution should support the load balancing methods, not limited to Round-Robin, Weighted Round-Robin, Least Connections, Fastest Response, URI, Host, Host Domain Solutions should provide application & server health checks for well-known protocols like ICMP, TCP, TCP_ECHO, HTTP, HTTPS, etc. Solutions should maintain server persistency using Source-IP /Network, Hash Header, Cookie, RADIUS Attribute, and SSL Session ID persistency options Solution should support content routing and rewrite content Solutions should support custom scripting for SLB and content rewriting The solution should support one-to-one NAT, Source NAT (change source IP), DNAT (change destination IP), and Full NAT (change source & destination IP) The solution should support application (JavaScript) and text (CSS, html, xml, custom plain) compression/decompression for website acceleration Solutions should be capable of doing SSL offloading towards clients and SSL re-encryption towards the real servers. Solution should support SSLv3, TLSv1.0, TLSv1.1, TLSv1.2, TLSv1.3 Should support Layer 7 DNS load balancing, security, and caching Solution should support a full SSL forward proxy to inspect outbound traffic

Global Server Load Balancing	Solution should support load balancing of servers between different data centres The solution should support a hardened DNS server that can be deployed as the authoritative name server Solutions should have the ability to determine virtual server health by real-time connectivity checking The solution should have persistent responses for application transactions across multiple hosts. The solution should support dynamic proximity, which is determined by application response time (RTT probes), least connections, or byte-per-second. Solution should support DNS-based load balancing of inbound traffic. Solutions should support all DNS queries like CANME, A record, AAAA record, MX record, CNAME record, NS record, TXT record, and SRV record. Solution should support Response Rate Limit to keep the authoritative DNS server from being used in amplifying reflection denial of service (DoS) attacks. Solution should support DNS Security The solution should support DNS64 to allow the resolution of addresses from the IPv4 world by creating synthesized AAAA records for hosts where no AAAA record is available.
Web Application Firewall & Security Features	The solutions should be able to protect the web server from the following types of attacks: • Cross-Site Scripting • SQL Injection • Generic Attacks • Known Exploits • Trojans • Information Disclosure • Bad Robot • Credit Card Detection • Application Attacks
	The solutions should offer Web Application Vulnerability Scanning with the following signature types: • MIME Signatures • Message Signatures • Files Signatures • Context Signatures • Apps Signatures
	Solution should provide XML and SOAP detection and validation with the following cases: • XML Format Check • SOAP Format Check • XML Limit Check • WSDL Check • Schema Validation • XML XSS and SQLi Protection
	Solution should provide JSON detection and validation with the following cases: • JSON Format Check • JSON Limit Check • JSON XSS and SQLi Protection
	Solution should include a Data Loss Prevention (DLP) feature that allows Web Application Firewall (WAF) to prevent information leaks, damage, and loss.

	Solution should have the option to verify and enforce the below HTTP Header objects • Maximum URI Length • Illegal Host Name • Illegal HTTP Version • Maximum Cookie Number in Request • Maximum Header Number in Request • Maximum Request Header Name Length • Maximum Request Header Value Length • Maximum URL Parameter Name Length • Maximum URL Parameter Value Length • Maximum Request Header Length • Maximum Request Body Length
	Solution should have the option to verify and enforce the HTTP Method (CONNECT, DELETE, GET, HEAD, OPTIONS, POST, PUT, TRACE) objects
	Solution should provide full URL Protection
	The solution should be capable of providing XSS & SQL Injection Protection using URI Detection, Referer Detection, Cookie Detection, and BODY Detection
	Solution should provide protection against bot attacks
	Solution should have the ability to prevent, detect, and restore web defacement with multiple protocols (FTP/SSH/Windows File Share) supported.
	Solution should have the ability to prevent, detect, and restore Brute Force Attack according to the Host, URL Pattern, Login Failed Code, and IP Access Limit
	Solution should have the ability to protect/secure cookies from leakage by enforcing Cookie encryption, Cookie signing, and Max-Age on cookies
	Solution should be able to support multiple types (video, picture, text, audio) file restrictions using action-based file enforcing and file size restrictions
	Solution should have a network layer DDoS prevention technique using IP Fragmentation Protection, TCP SYN flood protection, TCP slow data flood protection policy.
	Solution should have an application layer DDoS prevention technique using HTTP flood protection, HTTP Connection Limit, and HTTP Access Flood.
	Solution should have L4 IP firewall policy to allow or deny traffic based on a source address, destination address, and service
	Solution should have Intrusion Prevention Service (IPS) to provide the latest defenses against stealthy network-level threats.
	Solution should support user tracking and authentication to provide accurate policies to prevent fraud.
	The solution should be capable of publishing web applications and offering backend SSO access
	Solution should support Two-Factor Authentication
	Should support GEO-IP-based protection

API Discovery & Protection	The Solution should have in-built Machine Learning based API Discovery and Protection for XML, JSON API, or RESTful API interface API discovery should be performed to inventory all externally exposed APIs API protection should be capable of rewriting API calls so that public-facing components don't reveal clues about the rest of the API that can expose sensitive data Machine Learning should identify behavior anomalies that can indicate credential stuffing, brute-forcing, or scraping attempts by attackers WAF should support Centralized API security solutions that enable the security team to see the full API attack surface, set policies, and manage incident response. The solution should have XML and JSON protocol conformance The solution should have a Mobile Application Identification module for mobile API protection
API Gateway & Security	WAF should have an in-built API gateway from day one. API Gateway should define API users to restrict access to APIs based on API keys API Gateway should provide API user management, API key verification, API access control, Rate limit control, and API call rewriting API Gateway should support the RSA algorithm to generate a token and should use the public key to encode, and the private key to decode a random string with a minimum length of 64 API Gateway should use JSON Web Token (JWT) to authenticate and authorize between an issuer and an audience API gateway should restrict Access IP address with respect to the API key so that it may only be used from the specified IP addresses API gateway should restrict HTTP Referrer with respect to API key so that it may only be used when the specified URLs are present in the Referrer HTTP header. API Gateway should be able to limit API call requests allowed per user in a certain number of seconds. API Gateway should be able to limit the maximum number of API call requests allowed in a certain number of seconds.
Log and Reporting Features	The solution should be able to locally store event (audit), alert & traffic information The solution should be able to send all log types above to an external syslog server Should have a Reporting Engine built in Should support integration with renowned SIEM tools like ArcSight, Splunk, Qradar, and others The log and reporting solution must support custom reporting on demand The solution should have a dashboard for data analytics where the top "N" information is displayed
Device Administration & Management	Should support VM/HW based central Management if required in the future Should support HTTP/HTTPS/SSH in interface management Solution should have In-built diagnostic utilities Should support role-based admin access. The device should support SNMP
MAF	Bidder must submit the Manufacturer Authorization form (MAF)
Warranty	Bidder should propose hardware & software for a three (03) year OEM warranty and RMA support.
Manufacturer's part number	Bidder should submit the BOQ of the proposed device, including the detailed part numbers and the Manufacturer's Warranty part number.

License	Bidder must offer necessary security licenses & subscriptions that include " Server Load Balance, Global Server Load Balance, IP Reputation and GeoIP, Malware protection, Credential Stuffing Defense, DLP, WAF, Sandbox, Advanced Bot Protection" for three years
Supporting Document	Bidder must submit the required performance document and compliance reference document for the proposed device.
Installation, Testing, and Commissioning	Bidder must carry out on-site installation, testing, and commissioning. In consultation with the IT Department, the bidder must configure appropriate security and administration-related policies, must integrate with other related hardware/software required to make the Network Functional, and shall provide respective documentation to the IT Division.

SFPs/Cables

SFPs, or Small Form-Factor Pluggable, are compact, hot-swappable transceiver modules used in networking to interface with fiber optic and copper cables. They enable the connection of network devices, such as switches and routers, to a variety of networks, providing flexibility in data transfer and connectivity options. SFPs support different types of network standards, such as Ethernet, Fiber Channel, and SONET, and can transmit data over various distances, depending on the type of fiber or copper cable used. When it comes to cabling, several types can be used with SFPs:

Fiber Optic Cables: These are used for long-distance data transmission and can include single-mode fibers (SMF) for long-range connections and multi-mode fibers (MMF) for shorter distances. SFP modules can adjust according to the type of fiber and the distances involved.

Copper Cables: SFP modules can also work with copper cables, such as Ethernet cables (e.g., Cat 5e, Cat 6, Cat 6a), which are suitable for shorter distances typically found in data centers.

Active and Passive Cables: Active optical cables (AOCs) integrate transceivers into the cable assembly, allowing for high-speed data transfer over longer distances than passive cables.

Overall, SFPs and their compatible cables are essential components in building flexible, high-performance networking environments, enabling organizations to adapt their infrastructure to their specific needs.

7.42.3.5. Server Virtualization

Virtualization is a transformative technology that abstracts and divides physical computing resources into multiple virtual environments, allowing for better resource management and

utilization. It enables a single physical server to host several virtual machines, each functioning as an independent system with its own operating system and applications. This approach not only maximizes hardware usage but also enhances flexibility, as IT resources can be easily provisioned, scaled, or migrated to meet changing demands. Additionally, virtualization simplifies disaster recovery, improves security by isolating workloads, and reduces costs by minimizing hardware requirements. As a foundational element of cloud computing, virtualization plays a crucial role in modern IT infrastructure, driving innovation and efficiency in various industries.

Technical Specifications

Item Name	Detailed Required Specification
Data Center Management	A centralized manager to manage & Control Virtual Infrastructure should provide full visibility and management of virtual machines and their infrastructure across multiple data centers in a single pane. Should ensure security and availability, simplify day-to-day tasks, and reduce the complexity of managing virtual infrastructure
	The Solution Should be able to integrate with third-party Software Provisioning Solutions like BMC Blade Logic, HPE Server Automation, Puppet, Chef, and MS SCCM
	The solution should provide complete visibility into all levels of infrastructure and applications through a single management console for multiple hypervisors, plus physical and cloud environments. Integrate monitoring dashboards for vSphere, Hyper-V, and Amazon, as well as third-party Management Packs for leading applications.
	The solution should be able to collect and analyze all types of machine-generated log data, for example, application logs, network traces, configuration files, messages, performance data, system state dumps, and more.
	The solution should enable administrators to connect to everything in their environment, e.g., operating systems, applications, storage arrays, firewalls, network devices, etc., providing a single location to collect, store, and analyze logs at scale.
	The solution provides an intuitive GUI-based interface that makes it easy to run interactive searches as well as deep analytical queries for quick, actionable insights.
	The solutions should provide Monitoring of OS level resources (CPU, disk, memory, network) for Windows and Linux OS, and physical hardware resources of ESX hosts. These monitoring capabilities, combined with patented analytics, should extend operational visibility and proactive management capabilities across the OS and physical infrastructure levels.
Compute Virtualization:	The solution must be in the 'Gartner' Top Ranking position.
	The solution shall provide a virtualization platform that sits directly on bare-metal server hardware with no dependency on a general-purpose Operating System, such as OS-related patches or vulnerabilities, for greater reliability and security
	The solution shall support up to 6 TB of RAM per virtual machine, with the capability to manage up to 2000 hosts centrally.
	The solution shall have the capability to create virtual servers with up to 128 virtual CPUs, 6128GB RAM in virtual machines for all the guest Operating systems supported by the hypervisor

	The solution shall allow heterogeneous support for guest Operating Systems like Windows end-user OS, Windows Server, Linux, such as Red Hat, SUSE, Ubuntu, and CentOS, Solaris x86
	The solution shall provide a content library to give a simple and effective way of managing virtual machine templates, virtual appliances, ISO images, and scripts
	The solution shall allow taking point-in-time snapshots of virtual machines to be able to revert to an older state if required
	The solution shall provide memory capabilities such as transparent page sharing, memory ballooning, memory compression, and hypervisor-level memory swapping to maximize memory utilization and optimization
	The solution shall be able to create a cluster out of multiple storage datastores and automate load balancing by using storage characteristics such as capacity and performance to determine the best place for a virtual machine's data to reside, both when it is created and when it is used over time
	The solution shall be able to migrate a virtual machine across different geographical regions
	The solution shall have high availability capabilities for the virtual machines so that if one physical server fails, all the virtual machines running on that server shall be able to migrate to another physical server running the same solution. The feature should be independent of Operating System Clustering and should work with Fiber-channel SAN, iSCSI SAN, NAS, or HCI
	The solution shall have the ability to provide zero downtime, zero data loss, and continuous availability for the applications running in virtual machines in the event of physical host failure, without the cost and complexity of traditional hardware or software clustering solutions
	The solution shall provide an in-built replication capability that will enable efficient array-agnostic replication of virtual machine data over the LAN or WAN. This feature shall enable replication at the virtual machine level and enable recovery point objects of as low as 5 minutes. Additionally, it allows the administrator to recover to a point in time beyond the most recent replication (up to 24 past replications)
	The solution shall be able to support the detection of hardware conditions of the physical host and proactively evacuate virtual machines before an outage occurs
	The solution shall provide network traffic-management controls to allow flexible partitioning of physical NICs, such as VLAN and PVLANS, bandwidth between different network-traffic types, and allow user-defined network resource pools with shares and limits to define Quality of Service
	The solution shall provide a built-in network resource pool to guarantee a minimal level of protection for virtual machines in the event of network contention
	The solution shall provide a resource scheduler to dynamically migrate virtual machines during contention based on CPU, memory, and network utilization
	The solution shall provide a virtual switch that can span across a virtual datacenter, and multiple hosts should be able to connect to it. This, in turn, will enable a single point of management for virtual machine networking in a virtualized environment
	The solution shall provide a data center-wide actionable patch compliance dashboard in the management console that enables compliance to baseline through automated scanning and patching

	The solution shall be able to allow or disallow promiscuous mode and sniffing of network traffic for a single virtual machine or multiple virtual machines for troubleshooting or packet capturing purposes
Container Platform	The solution should be deployed on-premises (multi-site) along with a future roadmap for hybrid/multi-cloud deployment.
	The platform should integrate with hypervisors hosted both on-prem and in the cloud, including existing virtualization platforms and proposed virtualization platforms.
	The platform should support multiple databases, including relational, hierarchical, distributed, object-oriented, document, graph, and NoSQL. At a minimum, MS SQL, PostgreSQL, and Sybase must be supported.
	The platform should support a broad range of programming languages, including Spring, Java, .NET, Python, Ruby, Node.js, Go, and others.
	The platform should have a reasonable process for backward compatibility as and when upgrades occur.
	The solutions should have an integration facility with 3rd party reputable backup solutions.
Intelligent operations	The solution should provide intelligent operations groups, which would provide operational insights into health, risk, and efficiency of resources by application, line of business, production workload, configuration types, and other relationship types. The group memberships should be updated to reflect changes in the environment dynamically to display accurate information in real-time, enabling IT to better align with business teams and operations.
Subscription & Support Services	THREE-Year's collaborative 24/7 support from OEM, same day response.

7.42.3.6. Windows Server License

To enable secure, scalable, and policy-compliant deployment of server-based applications and services within the TMC environment. This license forms the foundational operating system layer for core services, virtualization hosts, and critical backend systems.

Technical Specification

Item Name	Detail Required Specification
Product License Type	perpetual
Core License Packs	License must be 16-core packs (minimum)
Minimum Licensing Requirements	A minimum of 16 core licenses is required for each server
Editions and Virtualization Rights	Standard Edition: Allows for up to two virtualized operating system instances (VMs) or Hyper-V containers when all physical cores are licensed. For every two additional VMs, all cores must be licensed again
Client Access Licenses (CALs)	In addition to core licenses, Windows Server CALs are required for each user or device accessing the server
Warranty	Minimum Three Years

7.42.3.7. Database Management System (DBMS)

To provide a secure, high-performance, and scalable database platform for the Traffic Management Center (TMC), enabling structured data storage, analytics, transaction processing, and integration with various ITS subsystems such as VIDS, ASES, RWIS, VMS, ETCS, and ALCS Management.

The DBMS shall support centralized storage and retrieval of all mission-critical data, such as system logs, configuration settings, incident records, and historical analytics, ensuring seamless interoperability between TMC software modules and external applications.

Technical Specification

Item Name	Detailed Required Specification
Product License Type	perpetual
Hardware Requirements	Support Minimum 1.4GHz x64 processor
Memory Requirements	Support a Minimum of 4GB of memory
Storage requirement	minimum 6GB of available hard disk space is required
Operating System Compatibility	Windows: Compatible with Windows Server 2016 and later versions. Linux: Supports distributions such as Red Hat Enterprise Linux and Ubuntu. Containers: Supports deployment on Docker containers
Key Features	Data Integration: Manage both structured and unstructured data, breaking down data silos and enabling AI across all your data. Performance and Scalability: Take advantage of breakthrough scalability and performance to improve database stability and response times without application changes. Security: Achieve security and compliance goals using a database rated as least vulnerable over the last nine years. Business Intelligence: Includes tools for creating and managing online analytical processing (OLAP) and data mining applications
Client Access Licenses (CALs)	Minimum 5 Client Access Licenses are required for each user or device accessing the server
Warranty	Minimum Three Years

7.42.3.8. Network Management System (NMS)

To provide real-time centralized monitoring, configuration, diagnostics, and performance management of the entire TMC network infrastructure, ensuring high availability and proactive resolution of issues across all active components.

Technical specification

Item	Requirement
System Type	A centralized software-based Network Management System (NMS) is deployed within the TMC data center environment.
Monitoring Scope	Routers, switches, firewalls, servers, storage systems, and virtualization infrastructure.
Core Features	- Auto-discovery of devices via SNMP, ICMP, WMI, or API - SNMP v2/v3-based polling and traps - Real-time health and status monitoring - Bandwidth and traffic analysis per port/interface - Alerting via email/SMS on threshold breach - Dashboard-based visualization and map view - Customizable reporting and historical trend analysis
Deployment	Web-based centralized interface accessible from TMC secure workstations; multi-user access with role-based permissions.
Interoperability	Must support integration with ticketing systems and allow SNMP integration with third-party NOC/SOC systems.
Brand (Reference)	SolarWinds Network Performance Monitor, Nagios XI, Paessler PRTG, or equivalent.
Licensing	Perpetual or subscription-based licensing with a minimum 3-year support and update service.

7.42.3.9. Video Management System (VMS)

To manage, monitor, control, and record real-time video surveillance feeds from all IP cameras deployed at the TMC and ITS field locations, with support for centralized operations, multi-operator access, and incident correlation.

Technical Specification

Item	Requirement
System Type	IP-based Video Management System (VMS) software is hosted on TMC's local server and storage infrastructure.
Camera Integration	Supports ≥ 500 IP cameras, including fixed, PTZ, dome, and thermal types across roads, intersections, toll plazas, and control room areas.
Core Features	- Live and recorded video streaming - Motion and event-triggered recording - Multi-channel simultaneous display - Bookmarking, tagging, playback, and video export - Configurable alerts and alarms - Operator-level access control and audit logging
Analytics Integration	Supports integration with video analytics, automatic incident detection (wrong-way driving, illegal parking, etc.), and AI-based behavior analysis modules.
Interoperability	ONVIF-compliant system supporting third-party camera models and integration with ITS platforms, incident management tools, and emergency communication systems.
User Interface	Multi-display video wall support with user-customizable layout presets, real-time camera status indicators, and control room dashboard integration.
Licensing	Centralized channel-based licensing for a minimum 3-year period, supporting system upgrades, OEM maintenance, and additional camera onboarding.

7.42.4. Passive Elements

7.42.4.1. Smart Micro Data Center Solutions (MDC)

Among several alternatives, the Modular Data Center (MDC) solution has been selected for the Roads and Highways Department (RHD) due to its integrated architecture, environmental resilience, and scalability. Unlike traditional layered rack-based systems, which require separate provision of HVAC, power, monitoring, and fire protection, the MDC comes pre-configured with these passive infrastructure features, streamlining deployment and ensuring consistency with operational standards.

Compared to container-based data centers, which are constrained by fixed physical and expansion limits, the modular solution supports flexible growth through side-by-side cabinet extension. This ensures scalability, ease of maintenance, and futureproofing without disrupting existing operations. The MDC design also aligns with RHD's need for localized environmental control, secure monitoring, and 24/7 equipment availability in diverse climatic conditions across Bangladesh.

Technical Specifications

Related service/Features	Technical Specification
Integrated design	UPS, power distribution unit, monitoring system, and smart cooling are integrated in one cabinet, and the equipment cabinet can be flexibly expanded on both sides of the integrated cabinet.
Altitude	The operating altitude should not be more than 4000 m
Operating temperature	The operating temperature range should be: -20°C to $+50^{\circ}\text{C}$;
Storage temperature	The storage temperature range should be -40°C to $+70^{\circ}\text{C}$
Relative humidity	The relative humidity of the system should be 5% RH to 95% RH (non-condensing)
Aisle type	The system should be single-row Cold and hot aisle containment
Certification	Converged System: CE, VCCI, RCM, EMC UPS Product: CE, CE EMC, CE LVD, CB Cooling Product: CE, CB, CCC, EAC, CRAA, RoHS, and REACH, Transportation and Safety
Power Distribution and UPS System	The voltage of the system must be 380/400/415 VAC, 3Ph+N+PE
	The input frequency of the system should be 50/60 Hz
	Power: IT load power ≤ 36 kW.
	UPS: 20kVA, 3 Nos.
	UPS Redundancy: 2N+1
	UPS Power system: 80~280VAC, 40~70Hz, 1Ph+N+PE
	Input voltage range: 176~264 V AC
	Surge protection: CLASSII/C, In 20kA, I _{max} 40kA, 8/20us

	Environmental Specifications Of the UPS System:
	The operating temperature should be 0–40°C
	The humidity of the UPS system should be 0%–95% RH (non-condensing)
	The altitude of the UPS system should be < 1000 meters When the altitude is 1000–4000 meters, see IEC62040-3 to check how the UPS power is derated. (The output power is derated by 1% for each additional 100 m.)
	The storage and transportation temperature should be –40°C to +70°C
	Mains Input Electrical Specifications of the UPS System:
	The rated input voltage should be 220 V AC, 230 V AC, or 240 V AC (single-phase input) 380 V AC, 400 V AC, or 415 V AC (three-phase input)
	The input voltage should be 80–280 V AC, single-phase (When the voltage is 80–176 V AC, the load power is linearly derated to 40%–100%.) 138–485 V AC, three-phase (When the voltage is 138–305 V AC, the load power is linearly derated to 40%–100%.
	Input power factor (100% resistive load should be > 0.99
	The startup voltage range should be within 120–280 V AC
	The diesel generator input capacity of the UPS system should be at least 1.5 times the UPS rated capacity
	Bypass Input Electrical Specifications of the UPS System:
	Bypass voltage threshold should be Upper threshold: 10%/15%/20%/25%@220 V AC Upper threshold: 10%/15%/20%@230 V AC Upper threshold: 10%/15%@240 V AC Lower threshold: 10%/20%/30%/40%/50%/60%
	The bypass frequency tolerance of the UPS system should not be more than ± 6 Hz (configurable on the LCD)
	The bypass overload capability should be Load < 125%: continuous in bypass mode 125% ≤ load < 150%: 1 minute in bypass mode Load ≥ 150%: 100 milliseconds in bypass mode
	Output Electrical Specifications of the UPS System:
	The output power factor should not be less than .9
	The rated output voltage should be 220 V AC, 230 V AC, or 240 V AC AC (single-phase output; select a voltage system by setting a voltage level on the LCD): 380 V AC, 400 V AC, or 415 V AC (three-phase output; select a voltage system by setting a voltage level on the LCD.
	The output voltage tolerance should be $\pm 1\%$
	The Total harmonic distortion of output voltage (THDv) should be < 4% (non-linear load) < 2% (resistive load)
	The Crest factor of the UPS system should be a maximum of 3:1

	The Inverter overload capability of the UPS system should be 105% ≤ load < 125%: transfer to bypass mode after 5 minutes 125% ≤ load < 150%: transfer to bypass mode after 1 minute Load ≥ 150%: transfer to bypass mode after 100 milliseconds The UPS stops supplying power if the bypass is abnormal
	The dynamic voltage tolerance of the UPS system should be ±5%
	The average frequency tracking rate should be 0.5–2 Hz/s (single UPS) or 0.5–1 Hz/s (parallel system)
	The audible noise should not be more than 58dB
	The dimension should not be more than 130 × 430 × 757(H × W × D)(mm)
	The weight should not be more than 32kg
	The UPS system should have a communication protocol like USB (optional RS485/Dry contact/SNMP)
	Certifications:
	EN/IEC 62040-1; EN/IEC 62040-2; EN/IEC 62040-3; CE; CB; RoHS, REACH, WEEE, etc
UPS Backup System	Backup time: Total 15 minutes at 36kW Load
	Battery: Rechargeable Battery, VRLA Battery, 12V, 26Ah
	Battery Cabinet System: Battery Basic Cabinet Rack, 32 batteries in each cabinet
	Number of battery Basic Cabinet Rack: 3 Nos.
rPDU	The rPDU should be a monitoring type.
	Each rack should have two (2) Single-phase 32A full-height rPDUs
	The Socket of the rPDU should be an IEC socket type and have at least 24 ports
	Input rated voltage should be 200~240VAC
	Maximum input current should be 32A
	Input wiring should be rPDU should be Single-phase 32A full-height (single) 1Ph+N+PE
	Rated Power: 7 kW
	Output Power Distribution Specifications should be Single-phase 32A full-height: 20*C13+4*C19 (32A/1P)
	The rPDU system should monitor the input power, voltage, and current
	The MODBUS communication system should be equipped.
	The rPDU system should be equipped with LCD display
	The operating Temperature should be -5-40°C
	The storage Temperature should be -40-70°C
	The Relative Humidity should be 5%-95%
	The rPDU system should have Full-height vertical installation
	The rPDU system should be CE certified.
Cooling Unit	Indoor unit:
	Indoor unit installation mode: Rack-mounted
	Cooling mode: Direct expansion cooling, rack-mounted installation
	Indoor unit height (with a temperature control module): 11 U (ACC:1U, indoor unit:10U)
	Number of precision air conditioners: 4 (3+1)

Cooling capacity in standard working conditions: 12.5 kW (outdoor temperature: 35°C; indoor return air temperature: 37.8°C; humidity: 20% RH)
Compressor: DC variable frequency drive
Indoor fan: EC fan
The cooling system should be air-cooled
The power voltage should be 208–240 V AC
The power frequency of the cooling system should be 50/60 Hz
The frequency tolerance should not be more than ± 3 Hz
The maximum current should not be more than 3.3A
The refrigerant of the cooling system should be R410A
The cooling capacity of the system should be 12.5KW
The cooling system should have a Wet film humidifier system
Air supply mode: Horizontal air flow
Light load humidification: Available at 10% IT load in normal temperature conditions
Storage temperature: -40°C to +55°C
Indoor unit cooling air volume: 2600 m ³ /h
Pipe height difference between indoor and outdoor units: -8 m to +30 m
Dimension: 486 mm x 442 mm x 800 mm
The net weight of the indoor unit should be 49.4 kg/66.8 kg
The IP rating of the cooling system should be IP20
Outdoor Unit:
The voltage of the outdoor unit should be 208–240 V AC
The frequency of the outdoor unit should be 50/60 Hz
The maximum operating current should not be less than 30A
Dimensions: 865 mm x 1040 mm x 410 mm (H*W*D)
Net weight/Gross weight of the outdoor unit should not be more than 82 kg/99 kg
The IP rating of the outdoor unit should be IP X4
Operating Environment:
The Indoor unit operating temperature range should be 0–40°C
The Indoor unit operating humidity range should be 5%–95% RH (non-condensing)
The outdoor unit's operating temperature range should be: For high-temperature outdoor units: -10°C to +55°C For normal-temperature outdoor units: -20°C to +45°C For low-temperature outdoor units: -40°C to +45°C
The outdoor unit operating humidity range should be 5%–95% RH (non-condensing)
The altitude of the cooling system should be 1000–4000 m. The performance of the smart cooling product is derated when the altitude ranges from 1000 m to 4000 m. The maximum outdoor operating temperature decreases by 1°C, and the nominal cooling capacity decreases by 1% for each additional 200 m
Installation Mode:

	The Installation Mode should be rack-mounted.
	The Vertical difference between the Indoor and Outdoor unit Outdoor unit placed higher than the indoor unit: ≤ 30 m Indoor unit placed higher than the indoor unit: ≤ 8
	Maximum Equivalent Length of One-way Pipe should be 80 m
	The thermal insulation foam thickness should be ≥ 13 mm
System Structure	Dimensions:
	Module (W x D x H): W x 1350 mm x 2000 mm
	Server cabinet (W x D x H): 600 mm x 1350 mm x 2000 mm (including cold aisles)
	Network cabinet (W x D x H): 800 mm x 1350 mm x 2000 mm (including cold aisles)
	IT Cabinet: Front Glass Door
	Aisle width: 250 mm
	Cabinet height: 2000 mm
	Total Cabinet: 14 (1 Converged Cabinet, 9 Server Cabinets, 1 Network Cabinet, 3 Battery Cabinets)
	Available space: 398U
	IT cabinet bearing capacity:
	Static load: 2400 kg
	Dynamic load: 1000 kg
	Cabinet door of Cold and hot aisle containment:
	Front door: double-layer hollow glass door
	Rear door: single-swing sheet metal door
	IP rating: IP20
	Installation mode: Installed on an ESD floor or a concrete floor
	Engineering workload:
	Cabling design: The input power cables for the module can be routed from the top or bottom. The power cables inside the module can be routed from the top.
	Sensor-Non positioning water immersion sensor
	Sensor-NTC Temperature Sensor - -20-70degC-+/-1degC
	Network Accessory-Smart ETH gateway-48VDC-POE
	Network Accessory-ETH Converter--RS-485/CAM converter to FE-POE
	All related power and signal cables included
	Main power input cable (60m considered) 600V/1000V,(4x50+1x25)mm ² ,179A
	PAC indoor-outdoor Cooper pipe included (30m each unit)
	Piping design: Pipes can be routed from the top or bottom. Pipes for indoor and outdoor units are welding-free.
Camera System	In a module camera system with SD Card, Video Camera, FE/DC12V/POE/SD card, Storage time ≤ 7 d;2nos
Monitoring system	The management system consists of the management software and other components. The ECC800 provides the real-time status, alarms, and configuration information about the equipment inside the smart module for management. It also provides a graphical user interface (GUI) for ease of operating and maintaining equipment inside the smart module.

	Function: Remote web page access and unified management of multiple branches
	Local monitoring: 10-inch tablet screen, supporting facial recognition login and keyless door opening
	Standard functions: Input power meter, Smoke sensor, T&H sensor, intelligent lock, 10-inch PAD, SMS/email alarm, local app O&M, Fire extinguishing module, video surveillance, water leakage sensor, and mobile O&M, PUE display
	Water sensor: Rope Type
	Smoke sensor: Standard configuration (inside the module)
	Temperature and humidity sensor: Standard configuration
	Temperature sensor: Standard configuration
	Power distribution monitoring: input voltage, frequency, current, and power, as well as the UPS input voltage, frequency, current, and switch temperature
	Smart cooling product monitoring: supply and return air temperature and humidity, Monitors and displays the fan speed, and displays the running percentage, displays the cooling load rate, Monitors and displays the compressor running status, heating, and humidifying.
	Local app: Standard configuration
Service, Support, Warranty & Subscription Services	Mentioning the Manufacturer's warranty, a minimum of three (03) years' warranty should be provided for this unit from the date of commissioning. (Except battery) Battery standard warranty is 1 year.
Authorization	Bidder must provide the Manufacturer Authorization Letter

7.42.4.2. Air Conditioning and Precision Cooling System

A. Precision Air Conditioning System (PAC)

Application Areas: Data center/server rooms requiring high-precision environmental control (temperature and humidity)

Technical Specification

Component	Specification
Cooling Type	Direct Expansion (DX) or Chilled Water (CW), air-cooled or water-cooled condenser options
Precision Control	±1°C temperature and ±5% RH humidity control
Air Distribution	Up-flow or down-flow delivery with an antistatic filter and an EC fan system
Redundancy	Configurable in N+1 for critical areas
Compressor Type	Scroll or digital scroll with inverter control for energy efficiency
Monitoring and Alarm	Microprocessor-based controller with LCD display, remote connectivity via BACnet, Modbus, or SNMP
Power Supply	400V ±10%, 3-phase, 50 Hz
Sound Level	≤65 dB(A) at 1 meter
Certifications	ISO 9001, ISO 14001, CE, and ROHS compliant

B. Split-Type Inverter Air Conditioning System

Technical Specification

Wall-mounted or ceiling-suspended split air conditioning systems consisting of indoor fan coil units and outdoor condensing units, suitable for continuous use in IT and control room environments.

Component	Specification
Indoor Temperature Range	27°C–30°C DB / 19.5°C–22°C WB
Outdoor Temperature Range	15°C–40°C DB
Indoor Unit Features	Direct expansion fan coil, washable air filters, motorized louver, remote control, and max noise level ≤ 44 dB(A) at 1 meter
Outdoor Unit Features	Hermetically sealed rotary or reciprocating compressor, weatherproof casing, copper condenser coil, fan interlock, vibration-isolated compressor mounting, sound level ≤ 65 dB(A) at 1 meter
Electrical Power Supply	$\leq 30,000$ BTU/h: 200–250V, 1-phase, 50 Hz; $> 30,000$ BTU/h: 380–440V, 3-phase, 50 Hz
Compressor Refrigerant	CFC-free, environmentally compliant refrigerant
Certification	ISO 9001, CE, or UL listed manufacturing standard

C. Support Systems

1. Auto Timer Control Circuit for Server Room

Electronic programmable timer circuit with auto-switch on/off for split AC operation in server room at configurable intervals (e.g., 4Hr/8Hr), integrated with magnetic contactors.

2. Ventilation Fan

High-CFM axial or propeller-type exhaust fan, complete with non-return damper, housing, accessories, and civil/electrical installation.

3. Refrigerant Pipe and Insulation

Copper piping with PVC conduit protection, nitrile rubber insulation (19mm for precision/split units, 13mm for smaller units), with appropriate fittings and hangers as per site condition.

4. Condensate Drain System

Properly sloped PVC/HDPE drain piping with U-trap, cleaning access, and vent system in line with HVAC best practices.

5. Communication Cable

Fire-retardant, shielded twisted pair cables between indoor and outdoor units, compliant with IEC/EN cabling standards.

D. Electrical and Power Panel System

Item	Specification
Panel Type	Wall-mounted/rack-mounted Distribution Boards (DB/SDB) with dead-front protection, designed for 240/400V, 3-phase, 50 Hz
Breakers	MCB/MCCB with thermal-magnetic tripping, inverse time delay, tropicalized components, compliant with BS 3871, IEC 60947-2
Interrupting Capacity	Ranges from 16 KA ($\leq 60A$) to 85 KA (600A–3000A) depending on frame size
Mounting	DBs shall be installed at 650mm–1800mm from floor level; final location adjustment allowed up to ± 5 mm from layout
Markings	All phases and breakers labeled clearly, with circuit directory included on/in panel door
Compliance	Panels and components must comply with BS 4649, BS 6004, BS 6346 or equivalent VDE standards
Cable Type	NYY insulated stranded copper cables, 600/1000V grade, with appropriate conduit, trunking, and support

7.42.4.3. Access Control System

The Access Control System and its components shall meet the following requirements:

Item	Description
Access Control (Central Controller Based)	Central controller supporting up to 2 doors locally and at least 32 readers in total using expansion i/o modules, integration software with a license of the following specification or equivalent input voltage: 12-24 Vdc $\pm 20\%$, micro-SD supported, Ethernet Communication: 10BaseT/ 100Base-TX Inputs: At least for the exit button and the door contact Outputs: minimum 3, relay type. Necessary power supply unit, enclosure included. Operating temperature: 0°C - +55°C Regulatory: CE/UL/FCC. Accepted /approved by the Engineer-in-charge.
	Designed for Shall One power supply and two batteries.
	A power supply unit with an integrated battery charging device
Proximity Card reader	Proximity Card reader of the following specification or equivalent. Typical card range: 6 cm minimum Operating Voltage: 5-16 Vdc Operating temperature: -35°C to +66°C Environmental Rating: Indoor/Outdoor Transmit Frequency: 13.56 MHz or 125kHz Certifications: CE/UL/FCC. Accepted /approved by the Engineer-in-charge.

	IP55 rating allows for indoor and outdoor installations (additional gasket improves rating to IP65)
Proximity Card	Supply of proximity card of 13.56 MHz or 125 KHz, transmit frequency with both sides printable feature, accepted/approved by the Engineer-in-charge.
	IP55 rating allows for indoor and outdoor installations (additional gasket improves rating to IP65)
Electromagnetic Door Lock	Electromagnetic door lock of the following specification or equivalent: 600lbs holding force, Dual voltage 12 & 24 Vdc Current drawn 500mA / 250mA MOV surge protection, Push-off button on armature for instant release. Dimension: - Magnet: 250(L) X 40(W) X 26(D) mm +-10% Armature Plate: 170(L) X 38(w) x 11(D) mm +-10% Operating Temperature: 0-55° C (32-131°F) Operating Humidity: 0-95% (non-condensing) Accepted and Approved by the Engineer-in-charge.
Exit Button	Exit button of the following specification or equivalent controlled by the door controller- unlocks the door when it is pressed. Operating Voltage: 10-14 Vdc or 125-250 Vac Operating Temperature: -20°C - +55°C Accepted /approved by the Engineer-in-charge.
Break Glass Unit	Break glass unit for emergency door release of the following specification or equivalent: Double pole double throw contacts (NO/NC/COM), Resettable with key, Status indicator, Embedded or surface mounting options. Accepted /approved by the Engineer-in-charge.
CAT-6 Cable	Supply, installation, testing & commissioning of UTP (unshielded twisted pair), LSZH (Low Smoke Zero Halogen) Cat-6 cable with the following specifications or equivalent as per the direction of the Engineer in charge. Physical specifications: Weight: 25.6 lbs. /1,000 ft. (37.34 kg/km) Jacket thickness:0.022 in (0.56 mm) Outside diameter: 0.232 in (5.89 mm) Maximum pulling tension: 25 lbs. (11.34 kg) Operating temperature: - 4°F to 140°F C20°C to 60°C) Electrical specifications: NVP (fastest pair @ 10 MHz): 690/o Maximum DC resistance: 7.61 ohms / 100 m Maximum DC resistance unbalance: 3% Mutual capacitance at 1 kHz:5.6 nF/100 m ANSI/TIA-568-C.2 category 6. ISO/IEC 11 801: 2002 (edition 2) class E CENELEC EN501 73: 2002 (edition 2) category 6 ETL: CMR\
UTP CAT6 I/O Modular Power Cable	UTP CAT6 I/O Modular under the following features Technical Specifications: Standards: TIA / EIA 568-C.2 Category 6, ISO/IEC 11 801 Class E

	Material Type: Copper alloy. High-impact, flame-retardant, thermoplastic Conductor Gauge: 22-23 AWG for both solid and stranded Plug Insertion Life: IEC 60603-7 compliant plug Plug Retention Force: Minimum 133 N Termination Contact Plating: Nickel Termination: Insulation-Displacement Contact (IDC) Wiring: T56841 T5688 Current Rating: Minimum 500 Mohm Insulation Resistance: Minimum 750 times Plug Insertion Life: Minimum 750 times

7.42.4.4. PA (Public Address) System

Item	Description
Public Address Voice Alarm Controller	Integrated Public Address and Voice Alarm with built-in or separately installed 500W Class D amplifier, complete with microphone bases/call station and other accessories to Work as a single unit 8-zone VA/PA system of the following technical specifications or equivalent: Zonal Speaker Group: 8 Frequency response: 100 Hz- 13 kHz Impedance: 250- 600 ohm Amplifier: 500W, Class-D Power supply: 15-30 Vdc or 220-240 Vac, 50 Hz Operating Temperature & humidity: -10°C+50°C (14°F+122°F) & <95% without condensation CE Certified/UL Listed
Zone Call Station	Dual channel power amplifier including accessories of the following technical specifications or equivalent. Stereo Power Output: RMS (Dual Channels)- 8Ωx2: 2115W-350W, 4Ωx2: 350W- 460W. Bridged Mono Power Output: RMS- 8Ωx 1: 700W- 950W Frequency Response: 20Hz- 20 KHz Signal to Noise Ratio > 97 dB Total Harmonic Distortion (THD) <0.5% Power Supply: 120 or 230 Vac 50Hz. Class: AB/ D/ H CE Certified/UL Listed
Ceiling Speaker	Professional heavy duty, ceiling mounted speaker ideal for airports, lounges, convention centres, corporate boardrooms, hotels/hospitality, houses of worship, museums offices, of patois, spaces schools, theatres and theme parks, superior sound quantity, wide dispersion, and smooth off-axis coverage of following technical specification or equivalent Frequency range (nominal): 85Hz to 18 KHz. (+3db). Nominal impedance: 8Ω Nominal sensitivity (1w, 2m): 90dB SPL Components: LF & HF driver. CE Certified/UL Listed
Horn Speaker	Horn Speaker of the following technical specification or equivalent 15W-20W

	Sensitivity: 100- 110dB Frequency response: 400 Hz - 7.5 kHz Minimum IP 65 rating CE Certified/UL Listed
Microphone	Table-type microphone stand complete with arms and mic holder. Foreign. Complete with required accessories and conformity to specified codes & specifications of international standards. Model & sample to be approved by the Engineer in charge.

7.42.4.5. Fire Detection & Alarm System

The equipment and materials of the Fire Detection and Alarm System shall meet the following requirements:

Item	Description
Dry chemical powder type Fire Extinguisher	Multipurpose ABC dry chemical powder stored pressure type with manometer system fire extinguisher suitable for repeated use, complete with wall bracket, CO2 cartridge, easy refilling system, etc., as per sample accepted & approved by the Engineer. Mono Ammonium Phosphate-based 40% ABC dry chemical agent & which has moisture-proof, anti-caking properties. Working pressure: 12 BAR minimum & Test pressure: 25 BAR minimum. Proper fire rating (as per NFPA 10) according to the capacity of the extinguisher. The manufacturer's certificate shall have to be submitted if needed. Also, a sample of the dry chemical powder will be tested by the proper authority in BANGLADESH if needed.
Carbon-Dioxide type Fire Extinguisher	Carbon-di-Oxide type fire extinguisher suitable for repeated use, complete with wall bracket, discharge nozzle, etc., as per sample accepted & approved by the Engineer.
Addressable Type Fire Detection & Alarm System	Supply, Installation, Testing & Commissioning of Microprocessor-based analogue addressable type Fire Alarm Control Panel, Expandable up to 5 loops with 80 (4 x 20) character LCD display. The Loop capacity shall be able to take 198 analogue addressable devices in one loop. The System shall have a 3D event management interface to display facilities organized by building, floor, and device. The Panel shall have an inbuilt port for the Printer and Annunciator. System shall have sufficient numbers of programmable relay controls for controlling AHUs, pressurisation fans, ventilation fans at fire pump room, monitoring of fire sprinkler and fire hydrant pump, Minimum of 6 Amp Power Supply, automatic battery charger 24 volts sealed lead acid batteries sufficient for 24 hours normal working and then be capable of operating the system for 2 hours during an emergency condition. The panel complies with the latest Fire codes and standards, UL & FM Approved. All components, including enclosures, shall be UL Listed.
	Power supply (input power) shall be 240VAC. All circuits requiring system-operating power shall be 24 VDC and shall be individually fused at the control unit. The incoming power to the system shall be supervised so that any power failure will be indicated at the control unit. A green "power on" LED shall be displayed continuously while incoming power is present. The system batteries shall be supervised so that a low battery or depleted battery condition or disconnection of the battery shall be indicated at the control unit and displayed for the specific fault type. The system shall support 100% of addressable devices in alarm or operated at the same time,

	under both primary (AC) and secondary (battery) power conditions. Loss of primary power shall sound a trouble signal at the FACP. FACP shall indicate when the system is operating on an alternate power supply.
	Product data sheets for system components are highlighted to indicate the specific products, features, or functions required to meet this specification. Alternate or as-equal products submitted under this contract must provide a detailed line-by-line comparison of how the submitted product meets, exceeds, or does not comply with this specification. Wiring diagrams, Shop drawings showing system details including location of FACP, all devices, circuiting, and details of graphic annunciator. Operating humidity range: Up to 93% RH, non-condensing @ 90° F (32° C) maximum. Approvals: UL listed & FM approved.
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Battery	SLA Battery for control panel, 12V each 7.2 Ah
Smoke Detector	Intelligent Addressable Photoelectric Optical Smoke Detector with base Addressable type photoelectric smoke detector c/w standard Base. Comply with the internationally accepted standard "smoke detectors for fire protective signalling systems." Include the following features: The detector shall be self-restoring: detectors do not require resetting or readjustment after actuation to restore normal operation. Sensors shall be with a plug-in arrangement, and associated electronic components are mounted in a module that connects to a fixed base with a twist-locking plug connection. Base shall provide a break-off plastic tab that can be removed to engage the head/base locking mechanism. No special tools shall be required to remove the head once it has been locked. Removal of the detector head shall interrupt the supervisory circuit of the fire alarm detection loop and cause a trouble signal at the control unit. Sensors shall be with a quick-connect arrangement: Photoelectric sensor and electronics in a single-piece construction, which shall twist-lock onto a mounting base that attaches to a standard electrical box. Each sensor base shall contain an LED that will flash each time it is scanned by the control Unit (once every 4 seconds). In an alarm condition, the sensor base LED shall be on steadily. Each sensor base shall contain a magnetically actuated test switch to provide for easy alarm testing at the sensor location. Each sensor shall be scanned by the Control Unit for its type of identification to prevent inadvertent substitution of another sensor type. Upon detection of a "wrong device", the control unit shall operate with the installed device at the default alarm settings for that sensor; 2.5% obscuration for photoelectric sensor, 1350°F and 150°F rate-of-rises for the heat sensor, but shall indicate a "Wrong Device" trouble condition. The sensor's electronics shall be immune from false alarms caused by EMI and RFI. The detector shall be self-restoring: detectors do not require resetting or readjustment after actuation to restore normal operation. Sensors shall be with a plug-in arrangement, and associated electronic components are mounted in a module that connects to a fixed base with a twist-locking plug connection. Base shall provide a break-off plastic tab that can be removed to engage the head/base locking mechanism. No special tools shall be required to remove the head once it has been locked. Removal of the detector head shall interrupt the supervisory circuit of the fire alarm detection loop and cause a trouble signal at the control unit. Sensors shall include a communication transmitter and receiver in the

	mounting base, having a unique identification and capability for status reporting to the FACP. Sensor address shall be located in the base to eliminate false addressing when replacing sensors. Removal of the sensor head for cleaning shall not require the setting of addresses. UL listed temperature range shall be: 0° to 38°C, and operating temperature range shall be: 0° to 50°C, suitable for humidity range: 10% to 95% RH. Housing colour shall be Frost White. Smoke sensor ambient ratings: Air velocity = 0-2000 ft/min (0-610m/min)
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Supply Voltage	10 to 30V DC
Alarm Indication	Red LED
Alarm Current	Minimum 40mA, at 22.5V
Heat Detector	Intelligent Addressable Heat Detector Fixed Temp. & ROR With Base Heat detector / thermal sensor: combination fixed-temperature and rate-of-rise unit with plug-in base and alarm indication lamp; 135° F fixed-temperature setting except as indicated. The thermal sensor shall be of the epoxy-encapsulated electronic design. It shall be thermostat-based, rate-compensated, self-restoring, and shall not be affected by thermal lag. The heat sensors of fixed temperature sensing shall be independent of rate-of-rise sensing and programmable to operate at 135° F or 155° F. Sensor rate-of-rise temperature detection shall be selectable at the FACP for either 15° F or 20° F per minute. The Heat Sensors shall have the capability to be programmed as a utility monitoring device to monitor for temperature extremes in the range from 32-deg F to 155-deg F. UL listed temperature range shall be: 0° to 38°C and operating temperature range shall be: 0° to 50°C Shall be suitable for humidity range: 10% to 95% RH Housing colour shall be frost white.
Alarm Indication	Red LED, Flashing LED
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Horn with strobe	Notification Appliances (Hooter with Strobe) An addressable type audible horn with strobe for notification purposes shall contain an electronic module and a selectable address setting. The device shall be suitable for programming the high/low setting of the audible (horn) appliances. The horn shall be red in colour with/without "FIRE" lettering. The horn shall be suitable to produce a sound pressure level of 89 dBA @ 24VDC at low level as per NFPA Standard. The horn shall be suitable for mounting directly to a standard single-gang, double gang or 4" square electrical box, without the use of a special adapter or trim rings. Shall have suitable operating ambient temperature range: 0° to 45°C (Minimum) Humidity range: Minimum 93% RH at t00°F (38°C) Approvals: UL-listed / FM-approved. The Strobe shall be selectable at 15.30.75. or 110 cd
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Control Module	Intelligent Addressable Control Modules

	Intelligent Addressable Potential-free, Form-C, SPDT contact-based Control Module to trigger 3rd party utilities like AHU shut-off, Pressurization fan activation, Special notification activation, etc. The contact shall be rated for 2A@24Vdc (Resistive) & 1A@24Vdc (Inductive). The control module shall have an operating temperature range from 0°C to 49°C and a humidity tolerance of up to 93% RH, Non-Condensing. Module shall not necessarily require a control panel for field diagnostic, troubleshooting, addressing, and customer text-feeding. These activities shall be carried out with the help of a hand-held field diagnostic tool capable of transferring the back-up to the PC for later use at the FACP.
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Monitor Modules	Intelligent Addressable Monitor Modules Normally Open Dry Contact input. The Monitor Module shall have an operating temperature range from 0°C to 70°C and a humidity tolerance of up to 93% RH, Non-Condensing. Module shall not necessarily require a control panel for field diagnostic, troubleshooting, addressing, and customer text-feeding. These activities shall be carried out with the help of a hand-held field diagnostic tool capable of transferring the back-up to the PC for later use at the FACP.
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Addressable Short Circuit Isolator	Fault Isolator Module for isolating shorted, de-wired, and loose circuits between two successive fault isolators, and all mounting accessories, complete as required
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Exit Sign	"Exit light" complete with rechargeable battery, charge light, and other necessary accessories suitable for AC / DC power supply (220V single phase)
Fire resistance cable	FPLR/ FPLP/ FPL type UL-listed / FM-approved cable. PVC Insulation for each core shall be FR (Fire Rated) & Drain wire. Shield (Aluminum Foil tape/ PET tape) shall meet the minimum requirement as per NEC (National Electric Code), NFPA 70, or BS. Jacket shall be fire-rated. All electrical contacts shall be of brass/copper connected through a connector or soldering (no twisting shall be allowed). The work shall be carried out as per the direction & approval of the Engineer-in-charge.

7.330.4.6. Fire Protection System (Automatic Fire Extinguishing)

The Automatic Fire Extinguishing System must meet the following requirements:

Item	Description
Suppression Agent	
Item	Suppression Agent (GAS) NOVEC 1230
Chemical formula	Dodecafluoro-2-Methylpentane-3-one/CF ₃ CF ₂ C(O)CF(CF ₃) ₂
Molecular weight	316.04
Boiling point @ 1 atm	49.2°C (120.6°F)
Freezing point	-108°C (-162.4°F)
Heat of vaporization @ BP	88.0 kJ/kg (37.330 BTU/lb)

Solubility of H ₂ O in Novec 1230 fluid	<0.001% by wt.
Relative dielectric strength @ 1 atm (N ₂ =1.0)	2.3
Features	UL/FM-approved seamless cylinder with FK-5-1-12 (NOVEC-1230) clean agent gas for a gas suppression system. complete with pressure gauge, valve assembly, and necessary accessories with a safety burst disc and a safety cap, etc., in conformity with NFPA 2001. Cylinder shall be seamless steel type manufactured from billets & tested. The cylinder/valve assembly shall have suitable metallic protection for the valve, enabling the transportation cylinders' safety. The cylinder shall be super-pressurized with dry Nitrogen to 25 bars. The cylinder shall be capable of withstanding any temperature between -30 °C & 70°C. All cylinders shall be distinctly & permanently marked with the quantity of agent contained. The empty cylinder's weight. The pressurization pressure & the zones they are protecting. Storage pressure: 25 bar: Test pressure: From 150 bar to 300 bar. Cylinder should include a Syphon tube and a Support base/ Strap, complete with a Valve Assembly and a pressure gauge.
	The valve assembly shall be mounted directly on the cylinder & should NOT have any adapter provision between the cylinder & valve as per requirements. Each cylinder valve shall have a provision for fixing a supervisory pressure switch & a safety burst disc to protect the cylinder from overpressure. The cylinder valve shall have a disabling plug to prevent accidental discharge of the valve during transportation & installation. Each Valve is to be fitted with a pressure gauge for monitoring loss of pressure. The master cylinder valve is to be released electrically, which is performed by means of a solenoid valve arrangement. Pilot cylinder actuation & pneumatic devices shall be used only for the Slave Cylinder. The Clean agent gas is stored in seamless steel cylinders & dry nitrogen is added to provide additional energy to give the required rapid discharge. Purity (%) of Clean Agent: 99.99, Applicable Fire Class: Class A, B & C fires. Pressure range: 25 bar: clean agent gas should be UL Listed/FM Approved.
Local Fill and Refill Facility	Bidder Should Submit an MOU who have a local Fill and Refill Facility of Novec-1230
Hydraulic calculations	Hydraulic calculations should be submitted with the bid submission
Cylinder Assembly	Cylinder Assembly with label indicator The agent storage cylinder is a steel pressure vessel manufactured, tested, and stamped in accordance with DOT
Storage Pressure	24.5 to 35 bar Max
Test Pressure	From 150 bar to 300 bar
Compliance	UL Listed & ULC/FM Approved
Electric Solenoid 24V DC - Stackable	An electric solenoid valve is normally closed, and the valve requires electrical energy to remain open.
Electrical Properties:	24 V.D.C.

Pneumatic Actuator	Pneumatic Release Device/pressure Operated Control Head, which allows for pressure actuation. Slave cylinders are mounted directly on top of the slave cylinders' valve.
Steel Nozzles	Each nozzle is available with a 360°16-port (central), 180°7-port (sidewall) discharge pattern.
	360° (central) and 180° (sidewall) nozzles generate a reactive force opposite to the nozzle
	Orifices; pipe bracing shall be located as close as possible to the nozzle to prevent movement or damage.
	area of protection when multiple nozzles are discharged into the same hazard, the hazard
	Shall be divided into two equal coverage areas. 360° nozzles shall be centrally located.
	180° Nozzles shall be centrally located against the nearest wall.
	For protected spaces that exceed the maximum nozzle throw of: 22.6 ft. (6.89m) for a 360° nozzle or 35.8 ft. (10.9m)
Compliance	UL Listed NOVEC 1230 agent
Agent Storage Cylinder	80L Capacity Cylinder Assembly with label indicator
Steel Nozzle	Steel Nozzle UL Listed as per Hydraulic Calculations
Electric Solenoid 24V DC – Stackable	Electric Solenoid 24V DC – Stackable
Manual Actuator	Manual Actuator
Discharge Pressure Switch	Discharge Pressure Switch
Check Valves	1" through 1" 78FP Check Valves have a maximum Working pressure of 500 psi (34.5 bar).
Cylinder Front Strap	Cylinder Front Strap with Back Rack
Fire Extinguishing Panel	Extinguishing Area Control Panel with Gas release
Working Method	The gas discharge can be automatic using double knock detections or manual using an electrical key switch.
Indicators	Power Source, Power Failure, Zone Fire, Fault and Isolate, Bell Isolate, Auxiliary Trip Isolate, Gas Isolate.
Switch	Bell Isolate, Auxiliary Trip Isolate, Gas Isolate, Fault Buzzer Mute, Master Reset, Main on/off, Test Battery.
Delay Discharge Timer	Built-in and Adjustable
Power Supply Input	240V AC 50Hz
Operating / System	24V DC
Charger	Auto / Trickle
Cabinet	The system is housed in a compact enclosure, finished with signal red epoxy powder paint.
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Battery	SLA Battery for control panel, 12V each 7.2 Ah
Heat Detector Features	Heat Detector Fixed Temp. With Base
	With Base
	Fixed Temperature
	The detector shall have an operating temperature range from 0°C to 50°C and a humidity tolerance range up to 95% RH
	Non-Condensing

	These activities shall be carried out with the help of a hand-held field diagnostic tool capable of transferring the back-up to the PC for later use at the FACP.
Compliance Requirement	UL Listed
Supply Voltage	10 to 30V DC
Alarm Indication	Red LED
Alarm Current	40mA, at 22.5V
Smoke Detector	Photoelectric Optical Smoke detector with base Addressable type photoelectric smoke detector c/w standard Base. Comply with the internationally accepted standard "smoke detectors for fire protective signalling systems." Include the following features: The detector shall be self-restoring; detectors do not require resetting or readjustment after actuation to restore normal operation. Sensors shall be with a plug-in arrangement, and associated electronic components are mounted in a module that connects to a fixed base with a twist-locking plug connection. Base shall provide a break-off plastic tab that can be removed to engage the head/base locking mechanism. No special tools shall be required to remove the head once it has been locked. Removal of the detector head shall interrupt the supervisory circuit of the fire alarm detection loop and cause a trouble signal at the control unit. Sensors shall be with a quick-connect arrangement: Photoelectric sensor and electronics in a single-piece construction, which shall twist-lock onto a mounting base that attaches to a standard electrical box. Each sensor base shall contain an LED that will flash each time it is scanned by the control Unit (once every 4 seconds). In an alarm condition, the sensor base LED shall be on steadily. Each sensor base shall contain a magnetically actuated test switch to provide for easy alarm testing at the sensor location. The Control Unit shall scan each sensor for its type of identification to prevent inadvertent substitution of another sensor type. Upon detection of a "wrong device", the control unit shall operate with the installed device at the default alarm settings for that sensor; 2.5% obscuration for photoelectric sensor, 1350°F and 150°F rate-of-rises for the heat sensor, but shall indicate a "Wrong Device" trouble condition. The sensor's electronics shall be immune from false alarms caused by EMI and RFI. The detector shall be self-restoring; detectors do not require resetting or readjustment after actuation to restore normal operation. Sensors shall be with a plug-in arrangement, and associated electronic components are mounted in a module that connects to a fixed base with a twist-locking plug connection. Base shall provide a break-off plastic tab that can be removed to engage the head/base locking mechanism. No special tools shall be required to remove the head once it has been locked. Removal of the detector head shall interrupt the supervisory circuit of the fire alarm detection loop and cause a trouble signal at the control unit. Sensors shall include a communication transmitter and receiver in the mounting base, having a unique identification and capability for status reporting to the FACP.

	Sensor address shall be located in the base to eliminate false addressing when replacing sensors. Removal of the sensor head for cleaning shall not require the setting of addresses. UL listed temperature range shall be: 0° to 38°C, and operating temperature range shall be: 0° to 50°C, suitable for humidity range: 10% to 95% RH Housing colour shall be Frost White. Smoke sensor ambient ratings: Air velocity = 0-2000 ft/min (0-610m/min) Superior EMI protection diagnostic tool capable of transferring the back-up to the PC for later use at the FACP.
Alarm Indication	Red LED, Flashing LED
Compliance Requirement	UL Listed
Flashing Light	"Flashing light" complete with rechargeable battery, charge light, and other necessary accessories suitable for AC / DC power supply (220V single phase)
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Alarm Bell with strobe	Notification Appliances (Hooter with Strobe) An addressable type audible horn with strobe for notification purposes shall contain an electronic module and a selectable address setting. The device shall be suitable for programming the high/low setting of the audible (horn) appliances. The horn shall be red in colour with/without "FIRE" lettering. The horn shall be suitable to produce a sound pressure level of 89 dBA @ 24VDC at low level as per NFPA Standard. The horn shall be suitable for mounting directly to a standard single-gang, double gang or 4" square electrical box, without the use of a special adapter or trim rings. Shall have suitable operating ambient temperature range: 0° to 45°C (Minimum) Humidity range: Minimum 93% RH at t00°F (38°C) Approvals: UL-listed / FM-approved. The Strobe shall be selectable at 15.30.75. or 110 cd
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Manual Call Point	Addressable dual-action manual pull station with rotary address switch to programme the device from 01-99, and all mounting accessories complete as required. The devices shall be UL-listed & FM-approved. Addressable manual pull station: Double action.
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Abort Station	Should a Superior EMI protection diagnostic tool be capable of transferring the back-up to the PC for later use at the Fire Alarm Control Panel
Compliance Requirement	UL Listed & FM Approved and ULC Listed.
Exit Sign	"Exit Sign" complete with rechargeable battery, charge light, and other necessary accessories suitable for AC / DC power supply (220V single phase)
Gas Discharge Sign	Gas Discharge Sign
Evacuate Sign	" Evacuate Sign" complete with rechargeable battery, charge light, and other necessary accessories suitable for AC / DC power supply (220V single phase)
Caution Sign	" Caution Sign " complete with rechargeable battery, charge light, and other necessary accessories suitable for AC / DC power supply (220V single phase)

Mechanical items and Electrical fittings	
Accessories for the suppression Channel	Schedule 40 Seamless pipe 2" Dia,
	Schedule 40 Seamless pipe 1 ½" Dia,
	Schedule 40 Seamless pipe 1" Dia,
	Schedule 40 Seamless pipe ¾" Dia
Fire resistance cable	Fire resistance cable, UL listed
paint	Best Quality Local Painting, Berger or equivalent

7.42.4.7. Videowall

Videowall system shall meet the following minimum requirements:

Component	Specification
Video Wall Processing Server	
Operating System Drive	1 × 1 TB NVMe SSD (PCIe Gen 4.0)
Additional Storage Support	Up to 4 × 3.5" SATA HDD (Hot-swappable, RAID 5/6 supported)
CPU	Intel® Core™ i9-13900K (13th Gen, 24-Core) or AMD Ryzen Threadripper equivalent
RAM	64 GB DDR5 ECC (Expandable to 128 GB)
GPU	NVIDIA RTX A2000 or equivalent (6 GB GDDR6)
Decoding Capability	Hardware decoding up to 128 channels (4K/1080p H.265/H.264)
Network Interface	Dual 10 Gbps Ethernet
Power Supply	Redundant hot-swappable 800W PSU
Output Ports	HDMI 2.1, DisplayPort 1.4, DVI-D
USB Ports	USB 3.2 Gen2 (front/rear)
Video Wall Controller	
Controller Type	Rack-mounted modular controller with intelligent cooling
Input Interfaces	HDMI 2.1, DisplayPort 1.4, DVI-D, IP stream, 4K/8K capable
Output Interfaces	HDMI 2.1 / DisplayPort 1.4 with synchronized multi-channel 4K output
Synchronization Support	Genlock & Frame-lock supported
Control Interfaces	RS232/485, Web GUI, USB, IR Remote, IP-based API
Advanced Features	Multiview, Picture-in-Picture (PIP), quad-view
55" LCD Display Panels	
Resolution	Ultra HD (3840 × 2160 pixels)
Bezel Width	Ultra-narrow bezel (<0.88 mm combined)
Brightness	≥700 cd/m² with auto-brightness adjustment
Backlight	Direct LED with local dimming
Refresh Rate	≥120 Hz
Viewing Angle	178° (H/V)
Mounting	Front-serviceable design with tilt-adjustable precision brackets
Structure & Accessories	
Support Structure	Modular aluminum or steel video wall frame
Pedestals	Integrated base with cable channels
Signal Cables	HDMI 2.1 / DisplayPort 1.4, factory-certified, 10 m length
Optional: Modular LED Video Wall	

Pixel Pitch	≤1.2 mm (for close-range viewing in the control room)
Brightness	≥1000 nits with auto-dimming
Resolution	Configurable to 4K or higher, depending on dimensions
Cabinet Material	Die-cast aluminum, front serviceable
Connectivity	HDMI, DisplayPort, HDBaseT, IP streaming
Control Platform	Web-based wall management software with layout presets

7.330.4.8. Network Video Recorder

To perform decentralized video recording, playback, and streaming from IP cameras located at ALCS sites, toll plazas, and the main Traffic Management Center (TMC), supporting real-time and short-term storage with high resolution and multiple compression standards.

Component	Specification
Function	Network Video Recorder (NVR) for IP-based video surveillance at ALCS Sites and Main Control Center
Video Input Channels	Supports up to 128 IP camera inputs
Supported Resolutions	12 MP, 8 MP, 6 MP, 5 MP, 4 MP, 3 MP, 1080p, 1.3 MP, 720p, and other standard formats
Video Output Resolutions	Up to 3840 × 2160, 2560 × 1920, 1920 × 1080, 1280 × 1024, 1280 × 720
Video Compression Formats	H.265 / H.264 / MJPEG
Network Bandwidth	Incoming: ≥256 Mbps; Outgoing: ≥128 Mbps
Playback Channels	1 / 4 / 8 / 16-channel synchronous playback
Playback Features	Play, pause, stop, fast forward, fast backward, rewind, play-by-frame
Audio Input/Output	1 × RCA input channel; 1 × RCA output channel
Storage Configuration	
HDD Interface	4 × SATA interfaces
HDD Capacity	Minimum 6 TB per disk (expandable)
Network Interface	
Ethernet Port	1 × RJ45 10/100/1000 Mbps self-adaptive Ethernet port
Network Protocol Support	HTTP, HTTPS, TCP/IP, IPv4/IPv6, RTSP, SMTP, NTP, DHCP, DNS, DDNS, FTP, etc.
Power over Ethernet (PoE)	
PoE Ports	16 × PoE ports, compliant with IEEE 802.3af/at standard
Power Supply & Consumption	
Input Voltage	100V–240V AC, 50 Hz
Power Consumption	≤ 20W (without HDD); total ≤ 185W including PoE
System Reliability	
System Type	Embedded Linux with GUI/Web Interface
Construction	Rack-mountable industrial-grade chassis
Environmental Durability	Designed for 24/7 operation in secure control room conditions

7.330.4.9. Archival Video Storage and NVR System

To serve as a centralized, high-capacity, long-term video data storage system that ensures retention of surveillance footage for regulatory, forensic, and analytical use across ITS and TMC operations.

Technical Specification

Component	Specification
System Type	Centralized video archival storage solution integrated with the Video Management System (VMS) and NVRs
Storage Architecture	Scalable SAN/NAS or Unified Storage System with RAID configuration and redundancy features
Retention Capacity	Capable of storing surveillance video from all active IP cameras (≥ 500) for 3 years or longer, based on configuration
Video Format Compatibility	H.264/H.265 compression with support for recorded metadata, motion/event tags, and multi-resolution streams
Data Protection Features	- RAID 5/6 or higher redundancy - Snapshot and replication - Backup-to-disk and export support - Optional offsite/cloud integration for disaster recovery
Search & Retrieval	Timestamp-based and metadata-based video lookup with support for rapid retrieval and export
Management Interface	Web-based or dedicated management software with a dashboard, storage utilization reports, and alerting
Access Control	Role-based access with video access logs and audit trails
Scalability	Modular capacity expansion to accommodate additional camera channels or longer retention periods
Power & Reliability	Dual redundant power supplies and hot-swappable disks; suitable for 24/7 operation in secure, climate-controlled environments
Support & Licensing	Licensed storage management software with a minimum of 3-year OEM support, firmware updates, and training services

742.4.9. Other Components

A well-functioning Traffic Management Center requires not only core systems such as servers, video walls, and surveillance equipment, but also a robust infrastructure backbone to ensure operational continuity, safety, and efficiency. The following components provide essential support services that are critical for long-term functionality and resilience of the TMC.

1. Power Supply and Distribution

The power system of a TMC must be designed for reliability and redundancy. The **main power supply** should support both heavy-duty and general-purpose equipment using three-phase 400V AC for high-load systems (such as servers and HVAC) and single-phase 230V AC for standard utilities. The power capacity must be sized based on the total calculated load of the facility, typically ranging from 100 to 200 kVA, depending on the number and type of equipment. To safeguard sensitive electronic systems, industrial-grade surge protection devices rated for at least 400V and capable of handling surge currents of 100kA should be installed.

2. Backup Power Supply

To ensure uninterrupted operations during power outages, a **backup generator system** is essential. A diesel-powered generator with a minimum capacity of 250 kVA should be installed, equipped with an auto-transfer switch and an **automatic start mechanism** that activates within 10–15 seconds of mains failure. The fuel storage capacity should be sufficient to provide at least 48 hours of continuous operation under full load.

3. Online Uninterruptible Power Supply (UPS)

An **online double-conversion UPS system** should be used to protect critical infrastructure components, including servers, communication hubs, and control systems. The UPS should be modular and scalable, with an initial capacity of 120–200 kVA depending on critical load demands. It must be capable of providing at least 30 minutes of battery backup time and include **N+1 redundancy** for fault tolerance. Remote monitoring features must be integrated to allow real-time diagnostics and automated alerting via a centralized interface.

4. Raised Flooring System

The TMC's **server and control rooms** should incorporate anti-static raised flooring systems to allow efficient management of power, data cabling, and underfloor cooling. The raised floor should be constructed with high-pressure laminate surfaces supported by steel or aluminum frameworks, with a **minimum load-bearing capacity of 1,000 kg/sqm**. The floor height should be between 300 mm and 600 mm to accommodate cabling trays and airflow ducts.

5. Structured Cabling System (SCS)

A **Structured Cabling System** ensures a reliable and scalable foundation for all IT and communication systems. High-performance **Cat6A copper cabling** should be used for intra-room network connectivity, while **OM4 fiber optic cabling** should form the backbone for data transmission between core systems and zones. Modular patch panels should be used for both copper and fiber systems, and all installations should follow TIA/EIA-568C standards. Proper cable management through horizontal and vertical organizers with labeling ensures long-term maintainability and expansion capability.

6. Environmental Control System

Continuous environmental monitoring within server rooms and critical equipment zones is essential for operational integrity. A centralized **environmental control system** should include sensors for temperature, humidity, smoke, and water leakage. These sensors should feed data into a real-time monitoring dashboard that can also issue alerts via SMS or email. Recognized systems such as APC NetBotz, AKCP, or Sensaphone are recommended for reliability and integration compatibility.

7. Pest Control System

Protecting sensitive IT infrastructure from pests is often overlooked but is crucial in tropical or semi-urban environments. The TMC should deploy electronic pest deterrent systems, such as ultrasonic emitters, in addition to regular fumigation services. This multi-layered pest control strategy will prevent infestations that could compromise cabling, hardware integrity, or indoor air quality.

7.42.5 Operation and Maintenance of TMC

7.42.5.1 Functional Zoning and Space Requirements

To ensure proper segregation of TMC activities, the following functional zones shall be provisioned with appropriate floor space, HVAC, access control, and power redundancy:

Zone	Description	Key Features
Network Operations Center (NOC)	Central command and monitoring hub for ITS systems	Video wall, operator consoles, integrated dashboards
Server Room	Housing of active computing equipment (servers, storage, switches, firewalls)	Smart Modular Data Center (MDC), precision cooling, fire suppression, raised floor
Power Room	Housing UPS systems, batteries, and main electrical panel boards	Redundant UPS, rPDUs, backup generator interface
Monitoring Room	Separate enclosure for surveillance system operators and recorders	CCTV system consoles, video recorders, camera feeds
Maintenance Room / IT Workshop	Storage and workspace for maintenance personnel and spare parts	Workbenches, tools, component inventory
Meeting & Planning Room	Space for coordination meetings, reviews, and planning	Projector, whiteboard, conferencing tools
Rest and Utility Room	For 24x7 staff accommodation and basic utilities	Pantry, lockers, and a resting facility

7.42.5.2 Operational Staffing Requirements

TMC will operate 24x7 and require personnel in shifts. The suggested minimum manpower plan includes:

Role	Quantity	Shift Coverage	Key Responsibilities
TMC Operations Manager	1	General	Oversight, reporting, planning
ITS System Administrator	2	2 shifts	Server/network/storage maintenance
Traffic Monitoring Officers	6	3 per shift	Real-time surveillance and response
Database Administrator (DBA)	1	General	Traffic & incident database
Network Engineer	3	3 shifts	Switches, routers, and firewall monitoring
Power & Facility Technician	2	2 shifts	UPS, precision AC, electrical panels
Security & Access Controller	2	2 shifts	Manage physical access control
Support Staff / Cleaner	3	General	Housekeeping

7.42.5.3 System Maintenance and Monitoring

Effective system maintenance and monitoring are critical to ensuring continuous availability, performance optimization, and risk mitigation in the Traffic Management Center (TMC). The following structured protocols shall be implemented:

A. Hardware Preventive Maintenance

- **Scope:** Includes servers, network switches, storage arrays, firewalls, precision air conditioning (PAC), rPDUs, and UPS systems.
- **Frequency:** At least once every **three months** (quarterly).
- **Activities:**
 - Visual inspection and cleaning of hardware components.
 - Functional testing of fans, power modules, and network ports.
 - Disk health monitoring using OEM diagnostic tools (e.g., SMART status, RAID rebuild verification).
 - Inspection and calibration of PAC units and battery health tests on UPS systems.

B. Firmware and Patch Management

- **Scope:** Operating Systems (OS), BIOS/firmware of servers and storage, switch/router firmware, and firewall appliances.
- **Update Cycle:** **Monthly**, or immediately after critical vulnerability disclosure.
- **Procedure:**
 - Maintain a **patch register** with update logs.
 - Use staging/testing environments to validate firmware or software patches before live deployment.
 - Follow rollback procedures in case of failed updates.

C. Network Health Monitoring

- **Protocols:** Utilize **SNMP v3**, **NetFlow**, or **sFlow** for active monitoring.
- **Tools:** Centralized Network Management System (NMS) shall provide:
 - Device uptime/downtime reports.
 - Bandwidth usage analytics.
 - Link error, packet drop, and CPU/memory alert thresholds.
 - Auto-generated alerts for link failure or unauthorized port activity.

D. Backup and Disaster Recovery (DR)

- **Data Backup Policy:**
 - **Daily incremental backups** and **weekly full backups** using Commvault or equivalent solution.
 - Retention of backup copies for at least **30 days** locally and **90 days** offsite.
- **Disaster Recovery:**
 - Storage system to support **off-site replication via SAN** or object storage.
 - Semi-annual **DR simulation exercises** to validate recovery time objectives (RTO) and recovery point objectives (RPO).
 - Documentation of DR runbooks and test logs.

E. Security Audits and Log Management

- **Firewall Log Analysis:**
 - Real-time log forwarding to SIEM.
 - Daily review of access violations, port scans, and denial-of-service attempts.
- **SIEM Integration:**
 - Integration with systems like **Splunk, Qradar**, or equivalent.
 - Correlation rules to detect anomalies across firewall, IDS/IPS, and system logs.
 - Monthly audit reports reviewed by the IT security team.

F. Environmental Monitoring

- **Temperature & Humidity:**
 - Smart sensors connected to central monitoring (ECC800) for real-time alerts.
 - Alert thresholds configurable for early warning and pre-failure condition reporting.
- **Water and Smoke Detection:**
 - Rope-type water leak sensors installed beneath raised floors.
 - Smoke sensors installed in all equipment and power rooms with remote alerting.

G. Access Control and Surveillance

- **Access Logs:**
 - Biometric and RFID access control integrated with audit trail logging.
 - Logs retained for a minimum of **6 months**.
- **Video Surveillance:**
 - All zones under 24x7 surveillance with IP-based CCTV.
 - Minimum **30 days video retention** in VMS archive.
 - Surveillance system integrated with motion alerting and incident tagging.

7.42.5.4 Service Contracts and Support

Long-term serviceability and reliability of the TMC systems depend on robust OEM support, structured maintenance contracts, and a proactive training strategy. The following support mechanisms shall be in place:

A. OEM Support Contracts

- **Validity:** Minimum of **three (3) years** from the date of commissioning.
- **Coverage:**
 - **24x7 technical support** via phone/email/web portal.
 - Advanced **replacement of defective hardware** under RMA terms.
 - Full **firmware/software updates** for OS, firewalls, servers, storage systems, and network appliances.
 - Support for **API integration**, software license activation, and compatibility updates.
- **Documentation:**
 - All OEM support contracts must be supplied in the original.
 - SLAs should define **response times (≤ 4 hours)** and **resolution times (≤ 24 hours)** for critical issues.

B. Annual Maintenance Contracts (AMC)

- **Separate AMCs** shall be executed for:
 - UPS and rPDU systems (battery maintenance, diagnostics, cell balancing).
 - Precision air conditioners (PACs), including gas recharge, humidifier calibration, and airflow testing.
 - Electrical power distribution boards and control panels.
- **AMC Services:**
 - Biannual preventive checks.
 - Emergency breakdown response within **6 hours**.
 - Report submission after each site visit detailing performance metrics and observations.
 - Free firmware upgrade where applicable.

C. Training and Knowledge Transfer

- **Deployment Phase Training:**
 - At least **two sessions per role** (System Admin, NOC Operator, Technician).
 - Hands-on training on software interfaces (VMS, ECC800, NMS, UPS GUI, etc.).
- **Annual Refresher Training:**
 - Conducted by OEM or certified local representative.
 - Covering system updates, configuration best practices, threat management, and troubleshooting.
- **Training Documentation:**
 - Hard copy and digital user manuals.
 - Video tutorials or simulation walkthroughs (if available).

7.42.5. Measurement

Measurement for each item for the Traffic Management Center (TMC) shall be conducted based on the successful **delivery, installation, configuration, testing, integration, and commissioning** of the respective hardware, software, infrastructure, or service component, as per the detailed technical specifications and under the supervision of the Engineer. The following principles shall apply for measurement:

1. All components delivered to the site shall be verified against the Original Equipment Manufacturer's (OEM) delivery documents and the contractor's itemized Bill of Quantities (BoQ). Physical inspection shall confirm that part numbers, labels, packaging, and quantities conform to the specification.
2. Equipment must be installed correctly in the designated areas, such as rack enclosures within the Modular Data Center (MDC), power rooms, monitoring rooms, or control panels, as per site layout and integration drawings. Installation must conform to best practices in cable management, grounding, labeling, environmental safety, and accessibility.
3. Each item shall be powered on and functionally tested in the presence of the Engineer or designated authority. Equipment such as servers, switches, firewalls, and PAC units must

undergo operational validation, including interface activation, port mapping, IP assignment, and test communication with upstream/downstream devices.

4. For items involving software components (e.g., operating systems, virtualization platforms, NMS, VMS, database systems), measurement shall be based on proof of valid license delivery, activation logs, system accessibility, and execution of baseline test scenarios. OEM licensing documents, activation reports, and installation logs shall be included.

5. Equipment and software shall not be considered for measurement unless fully integrated into the larger TMC system, including MDC rack environment, power distribution system, precision cooling, structured cabling, and monitoring platforms. End-to-end functionality shall be demonstrated—for example, a firewall forwarding traffic to core switches, or a VMS receiving feeds from IP cameras and writing to archival storage.

6. Measurement of passive infrastructure (e.g., rPDUs, UPS, battery banks, raised floors, fire suppression, and structured cabling) shall include verification of load testing, continuity checks, system diagnostics, and sensor calibration where applicable. Each system must demonstrate operational readiness under simulated or actual load conditions.

7. Measurement for fiber optic and copper cabling shall be conducted by verifying installed lengths, termination standards (e.g., ANSI/TIA/EIA-568), port labeling, and test results (e.g., OTDR, cable certification). Conformance to bend radius, routing plans, and segregation by data/power shall be validated.

8. Measurement of smart monitoring systems (e.g., ECC800, NMS, VMS, environmental sensors) shall be based on system accessibility, real-time dashboard demonstration, alert generation, SNMP polling, and integration with local and remote user terminals.

9. Training sessions shall be measured based on the delivery of training modules, participant attendance records, session materials, feedback forms, and completion certificates. O&M support services shall be measured monthly or quarterly, based on preventive maintenance logs, incident reports, ticketing system summaries, and SLA adherence reports.

10. For all items, submission of system documentation, including installation manuals, as-built drawings, configuration backups, user guides, and warranty certificates, is mandatory for completion of measurement. No item shall be considered measured unless full documentation is provided.

Measurement shall be deemed complete only upon approval by the Engineer and verification that the delivered item or system performs satisfactorily in its intended role within the TMC architecture.

7.42.6. Payment

Payment shall be made only upon the full supply, installation, commissioning, and functional verification of each item or system, as confirmed by the Engineer. No partial payment shall be made for items that are delivered but not installed, or for systems that are incomplete or pending integration into the Traffic Management Center (TMC) infrastructure. All hardware components must meet the prescribed technical specifications and pass commissioning tests, while software components must be delivered with valid OEM licenses and confirmed to be fully activated, integrated, and operational.

Structured cabling, rack power distribution units (rPDUs), precision air conditioning (PAC), UPS systems, and smart monitoring equipment shall be payable only after successful installation and operation in the designated Modular Data Center (MDC) environment. Functional and integration testing shall be witnessed by the Engineer and supported with commissioning documentation. All relevant documentation must be submitted prior to payment processing. This includes but is not limited to: delivery notes, OEM activation certificates, license files, as-built drawings, configuration logs, user manuals, warranty certificates, and signed commissioning reports.

For overseas-sourced equipment and software, a mandatory inspection and verification process shall be conducted prior to shipment. The supplier must coordinate with the Engineer or Client's representative to enable inspection at the OEM's facility or designated logistics hub. Upon arrival, the local supplier shall facilitate post-landing inspection by producing all relevant OEM documentation, including bill of materials (BoM), compliance certifications, factory acceptance test (FAT) records, and original serial number documentation to ensure authenticity and conformity.

Considering the rapidly evolving nature of ICT, intelligent transport systems (ITS), and data center technology, this technical specification shall serve as a **minimum benchmark**. The supplier shall be obligated to offer upgrades or adaptations aligned with contemporary international best practices and OEM-recommended configurations, particularly in areas where improved performance, security, interoperability, or power efficiency can be demonstrated without compromising the overall system architecture.

For Operation & Maintenance (O&M) and Annual Maintenance Contracts (AMC), payment shall be made periodically, typically on a quarterly or annual basis, subject to the submission of service performance reports, verified SLA compliance logs, preventive maintenance checklists, and incident resolution records endorsed by the Engineer.

Training-related pay items shall be payable upon the verified delivery of scheduled sessions, confirmed through attendance logs, delivery of training materials, feedback reports, and completion certificates signed by both trainees and the Engineer.

Pay items shall be:

Pay Item No.	Description	Unit
1	Supply, Installation, and Commissioning of Modular Data Center (MDC) with integrated racks, power, cooling, and monitoring	Each
2	Supply and Installation of Online UPS System with Battery Bank and Monitoring Panel (≥ 120 kVA, N+1 configuration)	Lot
3	Supply and Installation of Battery Rack Cabinets with VRLA Batteries for Backup Power System	Each
4	Supply and Installation of Precision Air Conditioning (PAC) System for Rack or Aisle Cooling (N+1 Redundancy)	Each
5	Supply and Installation of Smart Rack Power Distribution Units (rPDUs) with Monitoring and Alerts	Each
6	Supply and Installation of Fire Detection and Suppression System for MDC with Clean Agent and Control Panel	Lot
7	Supply and Installation of Addressable Environmental Monitoring Sensors (Temperature, Humidity, Smoke, Water Leak)	Job
8	Supply and Installation of Intelligent Infrastructure Monitoring System with Local GUI and PAD (ECC800 or equivalent)	Each
9	Supply and Installation of Ventilation Equipment and Exhaust Fans with Auto Timer for Thermal Management	Job
10	Supply and Installation of Raised Flooring System (Antistatic, 600 mm, 1000 kg/sqm load rating)	sqm
11	Supply and Installation of Electrical Power Distribution Boards (Main/Sub Panel Boards) for IT Infrastructure	Job
12	Supply and Installation of Communication and Signal Cabling for Cooling, UPS, Fire, and Security Systems	Lot
13	Supply, Installation, and Commissioning of Rack Server with required CPU, RAM, SSD, RAID, and Management Features	Each
14	Supply, Installation, and Commissioning of Enterprise Storage System with RAID and Snapshot Capabilities	Each
15	Supply, Installation, and Commissioning of SAN Switches with a specified number of high-speed FC ports	Each
16	Supply, Installation, and Commissioning of Core Routers with multi-speed interface support and routing protocols	Each
17	Supply, Installation, and Commissioning of Core Firewalls with IPS, NGFW, and threat protection features	Each
18	Supply, Installation, and Commissioning of Core Switches with 10G/100G support and Virtual Chassis capability	Each
19	Supply, Installation, and Commissioning of Server Farm Switches with stacking, 1G/10G support, and PoE	Each
20	Supply, Installation, and Commissioning of Server Farm Firewalls with unified ththe reat management capabilities	Each
21	Supply, Installation, and Commissioning of Web Application Firewall (WAF) & Application Delivery Controller (ADC)	Each
22	Supply and Installation of Optical SFP Modules and Copper/Fiber Network Cables as per OEM specifications	Lot
23	Supply, Installation, and Configuration of Virtualization Platform including Management Console and Tools	Each
24	Supply and Installation of Windows Server License (Standard/Datacenter Edition) with CALs as required	Each
25	Supply and Installation of Enterprise-grade Database License (SQL/Oracle/PostgreSQL)	Each

26	Supply, Installation, and Configuration of Network Management Software (NMS) with SNMP and a dashboard	Job
27	Supply, Installation, and Configuration of Video Management System (VMS) with camera integration and archival	Job
28	Supply and Installation of IP-based Surveillance System with NVR and 30-Day Storage	Job
29	Supply, Installation, and Commissioning of Archival Storage System with long-term retention (minimum 3 years) and redundancy	Each
30	Supply and Installation of Access Control System (Biometric/Smart Card + Controller) for TMC zones	Job
31	Supply and Installation of Structured Cabling System with Termination, Patch Panels, and Testing	Lot
32	Supply and Installation of Rodent Repellent System for cable trays and equipment rooms	Job
33	Supply and Installation of Public Address (PA) System with speakers, amplifier, and paging mic	Job
34	Supply and Installation of Video Wall System for control room integration with real-time feeds	Job
35	Supply and Installation of Monitoring Room Consoles, Furniture, and Cabling Interface	Lot
36	Provision of Training and Knowledge Transfer for System Operators, Admins, and Engineers	Session
37	Provision of Annual Operation & Maintenance (O&M) Services for TMC Systems and Infrastructure	Year
38	Provision of Warranty and Subscription Support Services (Hardware/Software) for a Minimum of three (03) Years	Year

7.43. Optical Fiber Cable (OFC)

The deployment of Optical Fiber Cable (OFC) infrastructure is essential for enabling advanced road safety services, intelligent transportation systems (ITS), and seamless integration of real-time traffic monitoring, enforcement, and control systems across the RHD highway network. OFC provides a robust and high-capacity communication backbone that supports low-latency and high-reliability data exchange among roadside units, regional traffic control centers, and central databases.

In addition to performance advantages, OFC offers critical national data security benefits. Unlike commercial ISP-based or shared communication channels, which pose potential risks of unauthorized access, service interruptions, or cyberattacks, an RHD-dedicated OFC network can operate as a closed intranet system, minimizing exposure to external threats. Such a system is particularly important when handling sensitive national traffic data, enforcement records, or automated incident responses where data confidentiality and transmission integrity are paramount. Moreover, Roads and Highways Department (RHD) owns substantial stretches of right-of-way (RoW) along national highways, making it strategically and economically viable to install and maintain its own OFC network without relying on third-party land acquisition or leased infrastructure.

The technical specifications for OFC infrastructure under RHD are currently under development. Until finalized, design and implementation may reference the extensive study conducted under the Western Economic Corridor and Regional Enhancement (WeCARE) Project. The report titled “Report for Technical Specification on Design Consultant’s OFC Design and BOQ” (June 2024) offers context-specific guidance and validated best practices for OFC deployment in Bangladesh and may be used as an interim technical reference.

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DIVISION 8

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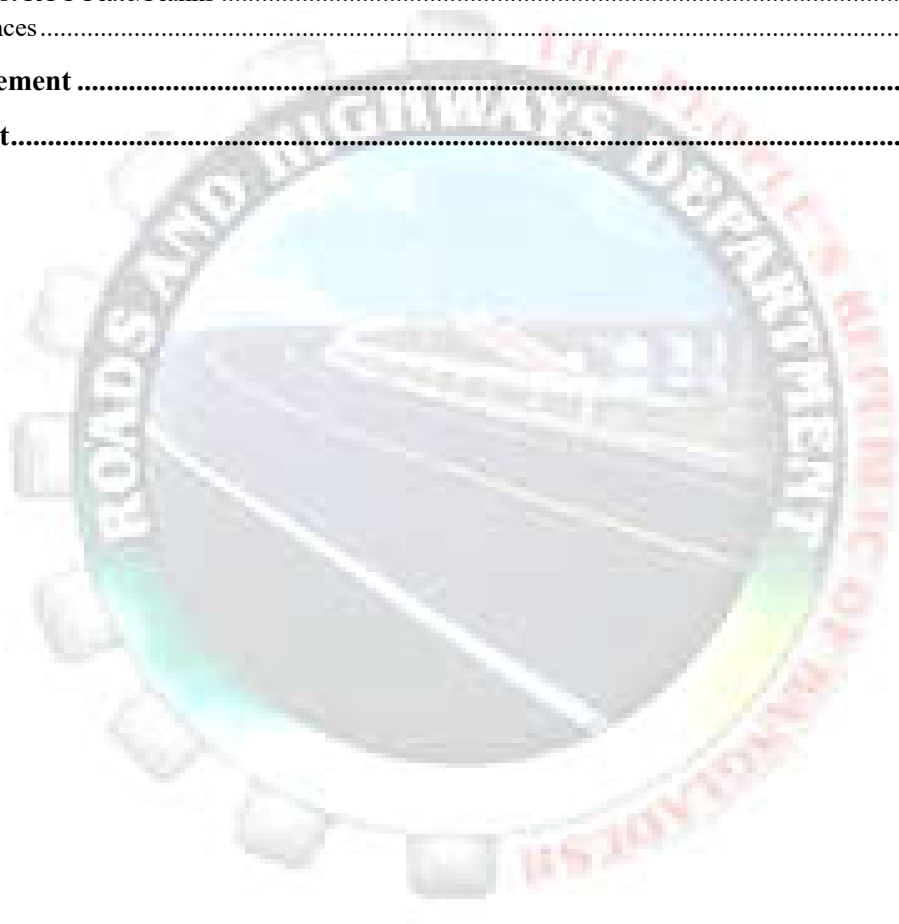
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8.1 Slope and Streambed Protection

8.1.1 Description

This work shall consist of the provision and installation of protection for stream banks, riverbanks, embankment slopes, cut slopes and other surfaces composed of erodible materials where protection is desired. Generally, protection to slopes will form an impervious layer constructed in or on designated surfaces and shall have at its bottom and ends anti-scour devices, such as cut-off walls or toe walls. Protection to the riverbanks shall form a graded aggregate scour protection.

The protection shall be constructed to the shapes and dimensions shown on the Drawings or as required by the Engineer.

8.1.2 Materials

8.1.2.1 Riprap Protection to Slopes

Stone for riprap shall consist of stone boulders of suitable size and shape. The stone shall be dense, resistant to the action of air and water, and suitable in all other respects for the purpose intended. Alternatively concrete blocks manufactured from stone chips maybe used, if shown on the Drawings.

The minimum thickness of stone shall be 100 mm (measured perpendicular to face of riprap). No face dimension shall be less than the thickness of the stone. Unless otherwise specified, the stones shall weigh not less than 10 kilograms each. The minimum thickness of the concrete block shall be 150 mm with a weight not less than 20 kg, with the concrete being Class 20 manufactured in accordance with Section 5.1 of the Specification.

8.1.2.2 Protection to River Bank

The following materials shall be used:

- a. Coarse gravel with sizes ranging from 5 - 40 mm and of approved grading.
- b. Cobblestones with sizes ranging from 50 - 100 mm and of approved grading.
- c. Boulders with sizes ranging from 100 - 200 mm.

The soundness of gravel and stones shall be approved by the Engineer.

The boulders shall be dense, resistant to the action of air and water and suitable in all other respects for the purpose intended.

8.1.2.3 Mortar

Mortar shall be composed of one part of cement and two parts of sand by dry loose volume and sufficient water to make a mortar that can be easily handled and trowelled. Retempering of

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mortar that has not been used for periods of 45 minutes or longer will not be permitted. Cement for mortar shall conform to the requirement of Section 5.1 of these Specifications.

8.1.2.4 Concrete Slope Protection

Concrete and reinforcement used in the construction of concrete facing for slopes shall be in accordance with Sections 5.1 and 5.2 of these Specifications, respectively, except where modified by the Drawings.

8.1.3 Construction Methods

8.1.3.1 General

A) Grouted Riprap

Unless otherwise specified riprap pavement shall always be constructed as an impervious layer upon designated surfaces. Unless otherwise specified riprap pavement shall have mortared joints and 40 mm weepholes per 2 m measured in both directions.

B) Loose Stone Riprap

Stone protection shall be carried out as shown on the Drawings.

The stone protection shall consist of the following layers:

Stone Type	Grading (mm)	Layer Thickness (mm)
Boulders	100 - 200	300
Cobble Stones	50 - 100	200
Coarse Gravel	5 - 40	150
Total		650

C) Concrete Slope Protection

Concrete slope protection shall be carried out as shown on the Drawings. Concrete shall be Class 20 and the reinforcement shall conform to the requirements of Section 5.2. The construction methods shall also conform to the requirements of Sections 5.1 and 5.2.

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8.1.3.2 Preparation**A) Grouted Riprap (stone or concrete blocks) and Concrete Slope Protection**

Excavation or construction of embankments shall be processed to planned shapes and dimensions, as if there were no protection, to allow some excavation immediately prior to the placing of the protection. The Contractor is responsible for discussing with the Engineer, his proposed method or constructing embankments in areas to be protected so that the proper procedure can be agreed.

The areas to be covered shall, at the proper time, be laid out to intended positions, and all necessary cut and fill stakes, batter boards, and construction lines set up. Every effort shall be made to have the surfaces in such condition as to require some excavation immediately prior to the laying of the protection. Where, however, low areas are encountered they shall be backfilled and thoroughly tamped at the earliest practical time in advance of the laying of masonry, to avoid settlement after placing riprap. It is not necessary that the entire area to be protected will be excavated and fine graded in advance of the laying. Work should always be laid upon a freshly excavated and stable surface.

B) Loose Stone Riprap

Stone protection work shall where possible be carried out during periods when low river levels allow construction in the dry. Approval of the Engineer shall be obtained prior to placing stone protection under water.

The area of the stone protection shall be prepared by excavating or dredging to the levels shown on the Drawings or as directed by the Engineer.

It is not necessary that the entire area to be protected will be excavated in advance of the laying. Gravel should always be laid upon a freshly excavated surface.

8.1.3.3 Cut-off Walls

Riprap and concrete slope protection shall always be accompanied by a bottom cut-off wall, unless otherwise instructed by the Engineer.

The cut-off wall shall be constructed of reinforced concrete to the dimensions and details shown on the Drawings. Concrete shall be in accordance with Section 5.1 and reinforcement in accordance with Section 5.2.

8.1.3.4 Laying**A) Riprap Protection and Concrete Slope Protection**

After cut-off concrete has been placed and accepted, the laying of slope protection shall be commenced in tight contact with the cut-off concrete and laid from the bottom towards the top.

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In the case of riprap protection the stones, boulders or concrete blocks shall be bedded on 50 - 100 mm of free draining sand or gravel as directed and shall be laid in close contact. The interstices may be partly filled with spalls or small stones. For the concrete slope protection, the reinforcing steels shall be laid and the concrete poured according to the requirements described in Sections 5.1 and 5.2.

Weep holes to riprap pavement shall be covered on the inside with stones and gravel filters extending 300 mm from the hole in all directions and connecting with the porous bedding material.

All joints and openings to riprap pavement shall be filled solidly with mortar.

Weep holes for the concrete slope protection and the joints shall be prepared and constructed as shown on the Drawings.

B) Loose Stone Riprap

All materials shall be transported and laid by methods, which do not cause damage to material previously laid.

Boulders shall be placed well packed and wedged together without mortar.

8.1.4 Measurement

Riprap and concrete slope protection shall be measured for payment on the basis of the area in square metres. Linear dimensions will be taken in not less than two directions, and of sufficient number so that averages can be obtained, and the product of the averages shall be the area considered for payment. Where slopes exist, measurement will be along the surface of the slopes.

Loose Stone Riprap shall be measured in cubic metres of stone protection as the total volume delivered by truck at site.

Concrete for cut-off walls shall be measured for payment on the basis of cubic metres. Length measurement will be taken along the front of the cut-off wall, while the width and depth will be the measurements given by the Engineer in writing. Excavation, formwork or reinforcement shall not be measured separately.

Material so measured shall be directly incorporated in the works or securely stored to the satisfaction of the Engineer.

8.1.5 Payment

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The work measured as provided above shall be paid for at the Contract unit prices per linear metre, square metre or cubic metre. The prices and payment shall be full compensation for furnishing all material, excavations whether shown or not and whether below water or not, concrete, reinforcement, forms if necessary, screening, curing, handling, backfilling if any, mortar, joints, weep holes, gravel filters, porous bedding, equipment, tools, labour and incidentals necessary to complete the work.

Pay items shall be:

08/01/01 Grouted Riprap Pavement (stone/concrete blocks to be specified)	Square Metre
08/01/02 Concrete Slope Protection	Square Metre
08/01/03 Loose Stone Riprap Protection	Cubic Metre
08/01/04 Concrete Cut-off	Cubic Metre

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8.2 Reinforced Concrete Culvert Pipes

8.2.1 Description

This work shall consist of concrete culvert pipes furnished and installed at such locations as are shown on the Drawings or as directed by the Engineer in accordance with these Specifications and in accordance with the classes, lines, levels, grades and dimensions shown on the Drawings.

The work shall include the furnishing and construction of such joints and such connections to other pipes, catch basins, manholes, walls and other items as may be required to complete the structure as shown on the Drawings. The work shall also include connection of existing drains, which have been interrupted by the road construction, to the new drainage system as directed by the Engineer.

8.2.2 Materials

8.2.2.1 Reinforced Concrete Pipe

Reinforced concrete pipes for culverts shall be constructed fully in accordance with the Drawings and Sections 5.1 and 5.2 of these Specifications.

8.2.2.2 Mortar

Mortar for joints shall contain one part Portland cement and two parts sand by dry volume unless otherwise required by the Drawings or the Specifications.

The amount of water in the mix shall be such that the consistency of the mortar is suitable for the purpose intended and to the satisfaction of the Engineer.

All mortar shall be used within 30 minutes of adding the water.

8.2.2.3 Reinforcement

Steel reinforcement shall be in accordance with Section 5.2 of these Specifications, except where modified by the Drawings.

8.2.2.4 Bricks

Bricks shall be in accordance with Section 5.5 of these Specifications.

8.2.3 Construction Methods

8.2.3.1 General

Pipes shall either be laid in existing ground, or if to be placed under the embankment fill this shall have been constructed to a height greater than the crown of the pipe in accordance with Section 2.6, before the Contractor will be permitted to excavate to place the pipes.

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8.2.3.2 Excavation

The width of the pipe trench shall be sufficient to permit satisfactory jointing of the pipe and thorough tamping of the bedding material under and around the pipe.

Before laying, the ground shall be trimmed true to line and grade, as directed by the Engineer, over sufficient width to permit satisfactory construction of the bedding. Special care shall be taken to remove any hard or deleterious material from the foundation area.

When soft, spongy or unstable soil is encountered; such soil shall be removed under the pipe for a width and to a depth as directed by the Engineer and replaced with sand or other suitable selected material properly compacted to provide adequate support for the pipe.

The prepared surface shall provide a firm foundation of uniform density throughout the length of the culvert.

Excavated materials classified as suitable should either be utilized as back filling, embankment fill or if surplus be stockpiled on site as described in Section 2.2.3.d of these Specifications. Excavated material classed as unsuitable shall be carried stockpiled as described in Section 2.2.3.c of these Specifications.

8.2.3.3 Bedding

Bedding for pipe culverts shall conform to the requirements given below for Class “A” or “B” bedding, whichever is called for on the Drawings or by the Engineer.

If the class of bedding is not shown, Class “B” bedding shall be provided.

- A) Class “A” Bedding - Concrete cradle for pipe culverts shall consist of a continuous concrete cradle constructed of Class 15 concrete in conformity with the details shown on the Drawings and the requirements of Section 5.1 of these Specifications.
- B) Class “B” Bedding - Class “B” bedding shall be constructed by bedding the pipe culverts in a trench cut in the natural ground or embankment to a depth as shown on the Drawings. The pipe culverts shall be bedded on a thickness of bedding material as shown on the Drawings accurately shaped by a template to fit the lower part of the pipe culvert exterior.

8.2.3.4 Installation

All concrete culvert pipes shall be laid with reinforced and mortared joints. The pipe shall be laid carefully and in straight lines. Before succeeding sections of pipe are laid, the lower half of the groove of the proceeding section shall be plastered on the inside with cement mortar of sufficient thickness to bring the inner surface of the abutting pipes flush and even. At the same time the upper half of the succeeding pipe shall be similarly plastered with mortar. After the

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pipe is laid, the remainder of the joint shall be filled with similar mortar, and sufficient additional mortar shall be used to form a bead around the joint. The inside of the joint shall be wiped and finished smooth. The mortar on the outside shall be protected with brickwork to allow backfilling to proceed.

8.2.3.5 Backfilling

Backfilling shall be carried out with material as indicated on the Drawings. It shall be placed in uniform layers not exceeding 15 centimetres in uncompacted depth and compacted as embankment fill for layers at the depths concerned below sub-grade. Special care shall be taken to compact the material under the haunches of the pipe and to ensure that the backfill shall be brought up evenly on both sides of the pipe.

Sand fill for bedding shall conform to the requirements for backfill of sand to structures in Section 2.5. Embankment fill shall conform of the requirements of Section 2.6.

8.2.4 Measurement

Culvert pipe shall be measured as the linear metres from end to end of each pipe structure, complete and accepted in place.

Excavation, bedding or concrete surrounding, backfill and tamped fill as well as cutting of holes for connection pipes will be considered incidental to the laying of the pipe and will not be measured as such. Headwalls shall be measured and paid for in accordance with Section 8.3.

8.2.5 Payment

Reinforced concrete culvert pipe measured as provided above shall be paid for at the Contract unit price per linear metre for the particular size specified on the Drawings. The price shall be full compensation for furnishing, hauling and installing the pipe, jointing, excavation, dewatering, pumping and bailing, bedding, backfilling, compaction and for all labour, tools, equipment and incidentals necessary to complete the work.

Pay items shall be:

08/02/01	Reinforced Concrete Culvert Pipe - Class A bedding	Linear Metre	(Diameter as Specified)
08/02/02	Reinforced Concrete Culvert Pipe - Class B bedding	Linear Metre	(Diameter as Specified)

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8.3 Drainage and Other Miscellaneous Structures**8.3.1 Description**

This work shall consist of the construction of all kinds of manholes, catch basins, drainage channels, pipe end walls, head walls and other miscellaneous structures in brickwork or of the required class or classes of concrete, with or without reinforcement constructed in accordance with these Specifications and to the lines, levels, grades and dimensions shown on the Drawings or as required by the Engineer. The work shall also include excavation, bedding and backfilling with suitable material in accordance with the Drawings and these Specifications. Some standard drawings has

8.3.2 Materials

Concrete shall conform to the requirements of Section 5.1. The concrete shall be Class 25 unless otherwise indicated on the Drawings.

Reinforcement, where required shall conform to the requirements of Section 5.2.

Brickwork shall conform to the requirements of Section 5.5.

8.3.3 Construction Methods**8.3.3.1 General**

Construction methods given under Sections 2.5, 5.1, 5.2 and 5.5 shall apply to this item unless otherwise described.

8.3.3.2 Manholes and Catch Basins

Manholes shall be completed before the adjacent roadway surfacing is placed. They shall not be constructed in Embankment areas, until the earthworks have reached sub grade level.

Frames for gratings and covers for manholes and catch basins shall be properly secured as indicated in the Drawings so as to be held rigidly in place to proper grade and alignment. Rocking gratings and covers will not be accepted.

Inlet and outlet pipe of manholes shall be set or cut flush with the inside faces of the walls of such structures and shall extend a sufficient distance beyond the outside faces of the walls to provide ample room for making proper connections. The joint around the pipe in the structure wall shall be completely and neatly closed with mortar, or other material as may be specified, so as to make it watertight.

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8.3.3.3 Concrete Side Ditch and U-Drain

Concrete Side ditches and U-drains shall be constructed to the dimensions and details shown on the Drawings.

8.3.3.4 Headwalls to Culvert Pipes

All headwalls to culvert pipes shall be formed in brickwork to the dimensions and details shown on the Drawings.

8.3.4 Measurement

Manholes, catch basins drains and Headwalls to culvert pipes will be measured for payment by number of each type as indicated in the Bill of Quantities, completed and accepted in place.

Excavation, side support if necessary, sand bedding, lean concrete inlet pipes, grate bars, slide gates, covers and gratings, ladder rungs, service pipes and house connection pipes will be considered incidental to the construction of the manhole and not measured as such.

Concrete side ditches and U-drains will be measured for payment by number of linear metres completed and accepted in place. Excavation, bedding, formwork, joints, covers etc. will not be measured separately except for reinforcing bar. The reinforcing bar shall be measured separately.

8.3.5 Payment

This work measured as provided above will be paid for at the Contract unit price for each particular item, such price and payment constituting full compensation for all material except for reinforcement, labour, tools, equipment and incidentals necessary to complete the work.

The complete work includes all work associated with the structure as indicated on the Drawings or in these Specifications. Pay items shall be:

08/03/01 Manhole (Diameter as stated in the Bill of Quantities)	Number
08/03/02 Catch Basin (Diameter as stated in the Bill of Quantities)	Number
08/03/03 Concrete Side Ditch (As detailed on the Drawings)	Linear Metre
08/03/04 Brick Headwall to Culvert Pipe (Pipe Diameter as stated in the Bill of Quantities)	Number
08/03/05 Saucer Drain (Brick Masonry) (As detailed on the Drawings)	Linear Metre
08/03/06aU Drain-Brick Masonry (upto 1000mm average height) (As detailed on the Drawings)	Linear Metre

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08/03/06bU Drain-Brick Masonry (upto 1500mm average height) (As detailed on the Drawings)	Linear Metre
08/03/07aU Drain-RCC (upto 1000mm average height) (As detailed on the Drawings)	Linear Metre
08/03/07bU Drain-RCC (upto 2000mm average height) (As detailed on the Drawings)	Linear Metre
08/03/07cU Drain-RCC (upto 2500mm average height) (As detailed on the Drawings)	Linear Metre
05/05/02 High Yield Reinforcing Bar	Tonne



8.4 Kerb, Gutter and Edge Detail

8.4.1 Description

This work shall consist of kerb, gutter, or combination of kerb and gutter, made of concrete or edging to the road pavement using whole bricks and constructed in accordance with these Specifications at the locations and in accordance with the lines, levels, grades, dimensions and types shown on the Drawings.

8.4.2 Materials

Concrete shall be of the grades and types indicated on the Drawings and shall conform to the requirements of Section 5.1.

Brick shall be selected Class “A” bricks of regular shape free from any defects or distortion. They shall conform in all respects to the requirements for first class bricks as specified in Section 5.5.2.1 of these Specifications.

Sand for bedding and infilling gaps between bricks shall be non-plastic and free from vegetable matter, soft particles and clay. It shall conform to either grading B or grading C of Table 2.8-1 of these Specifications.

8.4.3 Construction Methods

8.4.3.1 Concrete Kerb and Gutters

Excavation shall be made to the required depth, and the base upon which the kerb, gutter, or combination kerb and gutter is to be set shall be compacted to a firm, even surface. All soft and unsuitable material shall be removed and replaced with suitable material.

Kerb and gutter shall be cast in sections 3 metres or less with preformed filler 20 mm in thickness, to the size as shown on the Drawings.

Concreting shall be in accordance with the requirements of Section 5.1.

Forms shall be removed not less than 24 hours after concrete has been placed. Minor defects shall be repaired with mortar containing one part of Portland cement and two parts of fine aggregate.

Repair will not be permitted on the faces and rejected portions shall be removed and replaced at the Contractor's expense.

The finished work shall be true to line, grade and level to within 5 mm and shall present a smooth appearance free from kinks and distortion visible to the eye.

When kerbs are to be placed on minor structures or on rigid pavement, tie bars shall be inserted in the concrete as shown on the Drawings.

8.4.3.2 Edge Detail

The edge detail shall be as shown in the Drawings or as specified by the Engineer. The edge of the pavement hard shoulder and soft shoulder must be adequately compacted. Any damage caused to the pavement materials by compaction equipment due to the contractors method of [working shall](#) be repaired at the Contractors expense.

8.4.4 Measurement

The quantity measured for payment shall be the number of linear metres of the several types and sizes of concrete kerb, edge kerbs, the combination kerb and gutter or brick edging, completed in place and accepted. Concrete kerb, combination kerb and gutter and brick edging shall be measured in place along the front face of the kerb. No deduction shall be made for flattening of kerbs.

8.4.5 Payment

This work measured as provided above, will be paid for at the Contract unit price per linear metre for each particular item which prices and payments shall be full compensation for all excavation, backfilling and tamping, furnishing and placing all materials, including all labour, tools, equipment, forms, falsework, centering and incidentals necessary to complete the work.

Pay item shall be:

08/04/01	Concrete Kerb (As detailed on the drawings)	Linear Metre
08/04/02	Combined Concrete Kerb and Gutter (As Detailed on the Drawings)	Linear Metre

8.5 Topsoil

8.5.1 Description

This work shall consist of furnishing topsoil which has been removed from approved sources and transporting, spreading and thorough compaction of it on prepared surfaces in accordance with these Specifications and the Drawings.

8.5.2 Materials

Topsoil furnished by the Contractor shall consist of a natural friable surface soil without admixture of undesirable soil, refuse or foreign materials. It shall be reasonably free from roots, hard clay, coarse gravel, stones larger than 50 mm in any dimension, noxious weeds, tall grass, brush, sticks, stubble or other litter and shall have indicated by a healthy growth of crops, grasses, trees or other vegetation that it is free-draining and non-toxic.

8.5.3 Construction Methods

The Contractor shall notify the Engineer at least 5 days before he intends to start topsoil stripping operations. After inspection and approval by the Engineer, and prior to stripping the topsoil, the Contractor shall remove noxious weeds and tall grass, brush, large stones and roots.

The topsoil shall be evenly spread on the designated areas to a depth, which after settlement and compaction shall be that shown on the Drawings. Spreading shall not be done when the ground or topsoil is excessively wet or otherwise in a condition detrimental to the work. The roadway surfaces shall be kept clean during hauling and spreading operations.

After spreading has been completed, any large clods, large stones, roots, stumps and litter shall be raked up and removed.

To reduce erosion as much as possible, the placing of topsoil and the subsequent grassing shall be done simultaneously with or immediately after the placing and compacting of the individual layers of fill.

8.5.4 Measurement

The quantity measured for payment shall be the number of cubic metres of required topsoil of the designated thickness complete and accepted in place. If side slopes of embankments or excavation requiring top soil are of greater area than required due to earthworks not conforming to the required dimension, the area measured shall be the required area as if the earthwork had conformed to the required dimension.

8.5.5 Payment

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This work measured as provided above, shall be paid for at the Contract unit price per cubic metre. The price shall be full compensation for furnishing and placing all material, including all labour, equipment, tools and incidentals necessary to complete the work.

No payment will be made for topsoil until it has been grassed according to Section 8.7.

Pay item shall be:

08/05/01	Topsoil	Cubic Metre



8.6 Grassing

8.6.1 Description

This work shall consist of furnishing turf and sods as required and planting them to give a healthy stable covering of grass which will maintain its growth in any weather and prevent erosion of the material in which it is planted.

8.6.2 Materials

Grass shall be of species native to Bangladesh, harmless and inoffensive to persons and animals and not of a kind recognized as a nuisance to agriculture. It shall be free of disease and noxious weeds, deep rooted and sufficiently rapid growing and spreading to give complete cover over the planted area within the Defects Liability Period.

The term “grass” embraces turf and sods and, if the Engineer permits, may include plants of other types capable of giving effective protection.

Fertilizer shall be approved lime or mixtures of plant nutrients or both.

8.6.3 Construction Methods

Sodding or surfing shall be done by planting sods or turf, as indicated on the Drawings, to give continuous cover over the whole area. They shall be planted with their root systems substantially undamaged, well buried in firm material, and packed around with moist earth in which they have grown.

Grass shall be planted at such a time and the work shall be done in such a way that at the time of the final construction inspection all areas to be grassed are substantially covered with healthy, well established, firmly rooted grass and the planted area is free from erosion channels.

Surfaces to be planted shall be trimmed in such a way that the ground surface after planting shall be as shown on the Drawings.

Fertilizer shall be added at the time of planting if necessary to ensure good ground cover within the required time.

The Contractor shall maintain the grass at his expense until the end of the Defects Liability Period. Maintenance shall consist of preserving, protecting and replacing grass and such other work as may be necessary to keep it in a satisfactory condition to prevent erosion and to present a dense and uniform appearance. The Contractor shall be responsible for satisfactory growth and shall water, fertilize, and mow the grass at such intervals as will ensure good ground cover of live grass all through the Defects Liability Period.

8.6.4 Measurement

The quantity measured for payment shall be the number of square metres of turfed or sodded surface whether horizontal or sloping of required and accepted grassing well established in place. Fertilizer will not be measured separately.

8.6.5 Payment

This work measured as provided above shall be paid for at the Contract unit rate per square metre. Payment for grassing shall be made at the termination of the Defects Liability Period. The payment will be full compensation for furnishing all materials, labour, equipment, tools and incidentals necessary to complete the work to the satisfaction of the Engineer.

Pay items shall be:

08/06/01	Grass Sodding	Square Metre
08/06/02	Grass Turfing	Square Metre

8.7 Concrete Monuments and Posts**8.7.1 Description**

This work shall consist of furnishing and installation of concrete monuments and posts as detailed on the Drawings and at locations indicated on the Drawings or as directed by the Engineer.

8.7.2 Materials

Concrete monuments and posts shall be precast using concrete conforming to the requirements of Section 5.1. Reinforcement steel shall conform to the requirements of Section 5.2. Paint, if indicated on the Drawings, shall be of the appropriate type and color and to the approval of the Engineer.

8.7.3 Construction Methods

Construction, fabrication and installation of concrete monuments and posts shall be as shown on the Drawings.

8.7.4 Measurement

The quantity measured for payment shall be the actual number of concrete monuments and posts placed and accepted.

8.7.5 Payment

This work measured as provided above shall be paid for at the Contract rate for each monument and post. The price and payment shall be full compensation for furnishing and placing, including all materials, labour, equipment, tools, and incidentals necessary to complete the work.

Pay items shall be:

08/07/01	Concrete Monument	Number
08/07/02	Concrete Post	Number

8.8 Protection of Works

8.8.1 Scope of Work

Bridge abutments and culvert inlets shall be protected by brick mattressing laid over geotextile filter fabric in accordance with the Drawings and these specifications.

8.8.2 Bricks for Mattressing

8.8.2.1 General

This section specifies whole bricks for use in the Works.

8.8.2.2 Sampling

Whole bricks shall be sampled in accordance with Standard Test procedures Clause 1.1. Samples thus collected will be tested for crushing strength, unit weight and water absorption. Samples shall be collected from each batch of 5,000 bricks supplied, or more frequently as the Engineer may direct.

8.8.2.3 Dimension

First Class Bricks should have the following dimensions after burning, 250 mm x 120 mm x 70 mm. Picked Jhama (PJ) Bricks may have dimensions slightly below those for other brick but not less than 235 mm x 110 mm x 70 mm.

8.8.2.4 Appearance

Bricks shall be uniform in size and colour and shall emit a clear metallic ringing sound when struck one against another. They should have an even surface without cracks.

8.8.2.5 Unit Weight

The unit weight shall be determined in accordance with STP 7.8.3 (Compacted). The unit weight of 1st Class broken bricks shall not be less than 1100 kg/m³ and Picked Jhama broken bricks shall not be less than 1200 kg/m³.

8.8.2.6 Crushing Strength

The crushing strength of bricks shall be tested in accordance with STP 7.8.4. The average crushing strength of 1st class bricks shall not be less than 17 N/mm² and for PJ bricks shall not be less than 20 N/mm².

8.8.2.7 Water Absorption

The water absorption shall be determined in accordance with STP 7.8.3 for Material between 38 mm and 10 mm. The water absorption as a percentage of the dry weight shall not exceed 20%, for 1st class bricks or 15% for PJ bricks.

8.8.3 Geotextile Filter Fabric

Geotextile filter fabric used in the works shall be equivalent to Biddam U44 or Terram 2000 or polyfelt TS 650. The material shall be supplied in rolls and installed completely in accordance with the manufacturer's instructions.

8.8.4 Mattressing**8.8.4.1 General**

The Contractor shall construct mattressing over geotextile filter fabric consisting of bricks enclosed by wire mesh, and metal stakes consisting of 16mm diameter round reinforcing bar as shown on the Drawings to provide scour protection around structures and elsewhere as directed by the Engineer.

The geotextile fabric shall be placed on a smooth and uniform foundation, cleared and grubbed and compacted as for roadway embankment, prior to the installation of the mattressing.

8.8.4.2 Bricks

Brick used in mattressing shall be Picked Jhama bricks complying with the requirements of Section 8.11.2.

8.8.4.3 Galvanized Wire Mesh

Wire for mattressing shall be mild steel wire conforming to the appropriate British Standard and hot dip galvanized weaving to the requirements of BS 729.

The wire shall be not less than 2.5 mm in diameter and the minimum weight of zinc coating shall be 270 grams per square metre. The adhesion of the zinc coating to the wire shall be such that when the wire is wrapped six turns around a mandrel four times the diameter of the wire, it shall not flake nor crack to such an extent that any zinc can be removed by rubbing by fingers.

The mesh shall be hexagonal woven with the size of mesh no greater than 60mm by 80mm and joints shall be formed by twisting each pair of wires through three half turns. The shorter dimension shall be taken from centre to centre of the twisted joints and the longer dimension, which is nominal, from the ends of the twisted joints. The mesh shall be laid so that the longer dimensions of both the mesh and the bricks are at right angles to each other.

8.8.4.4 Placement

Bricks shall be placed in baskets approximately 2m width by 6m long and 200mm thick. Picked Jhama whole brick shall be first placed in the baskets so that the 110mm x 240mm face of the brick is vertical. Broken brick pieces of the size not smaller than 70mm x 57mm x 55mm are required to be randomly packed into the basket. Filling shall be carried out by

raking the broken bricks to achieve compaction with a slight overfilling so that the mattress top mesh must be stretched over the bricks and then tied in place. All baskets shall be wired together to form a continuous mattress with 3mm galvanized tie wire and where the baskets abut concrete structures they shall be firmly attached to the structure with 3mm galvanized anchor wire embedded in the structure as shown on the Drawings.

When placed on a slope, mattressing shall be constructed starting from the bottom of the slope and metal stakes consisting of steel reinforcing bars of the dimensions shown on the Drawings shall be driven through the mattressing at 1.5m centres.

8.8.5 Measurement

Measurement for payment for installing geotextile filter fabric will be made based on the area in square metres measured parallel to the face on slopes of mattressing installed as shown on the Drawings or directed by the Engineer. No additional payment will be made for fabric used to provide specified laps.

Measurement for payment for furnishing and installing mattressing will be made based on the area in square metres measured parallel to the face on slopes of mattressing installed as shown on the Drawings or directed by the Engineer. No extra measurement shall be made for cut off walls or edge thickening.

8.8.6 Payment

Pay items shall be:

08/8/01	Geo-textile filter fabric (as detailed on the Drawings or as directed by the Engineer)	Square Metres
08/8/02	Furnishing and installing mattress (as detailed on the Drawings or as directed by the Engineer)	Square Metres

8.9 Slope Protection Works by Palisading

8.9.1 Description

This work shall consist of providing slope protection work by Palisading in accordance with these Specifications and in conformity with the requirements of the Drawings or the Engineer's instructions.

8.9.2 Requirement of Wooden Piles

Wooden piles shall consist of best quality timber, Sal, Sundari or Garzon, the diameter of which shall be average 150 mm measured at 1/3 depth from the thick end and the length shall be minimum 6 metres.

For local bullah, wooden piles shall consist of best locally available timber, e.g., Gab, the diameter of which shall be between 150mm and 200mm and the length shall be minimum 6 metres as approved by the Engineer.

8.9.3 Construction Methods

A 1/3 rd of the length of wooden pile, but not less than 2.0 m below ground level, shall be driven at a spacing of 600 mm c/c. Two (2) layers of horizontal runners with half sawn bullah and drum sheet shall be fixed with gazali, nut, bolts etc. necessary tie wire and tie posts shall also be provided.

8.9.4 Measurement

The unit of measurement shall be the linear metre of Palisading works completed as per the drawing and accepted.

8.9.5 Payment

The work shall be measured as provided above shall be paid at the contract unit rate per linear metre. The rate shall constitute full compensation for all labour materials, equipment, driving, fitting, fixing and all related tools, hammers and other incidental equipment and works.

No payment shall be made for unauthorized or unsatisfactory works

Pay item shall be:

08/9/01(a)	Bullah Palisading (150mm – 175mm)	Lin. Metre
08/9/01(b)	Bullah Palisading (Local Bullah: 150mm – 200mm)	Lin. Metre

8.10 Mobilization for Deck Slab Repairing Work, ETC

8.10.1 Description

This work shall consist of mobilization of equipment, labour and materials for deck slab repairing work at locations as directed by the Engineer.

8.10.2 Materials

The materials for construction warning signs shall conform to the requirements of the Drawings and shall be of the appropriate type and colour and to the approval of the Engineer.

8.10.3 Measurement

The unit of measurement shall be square meters of deck slab actually repaired and accepted.

8.10.5 Payment

This work measured as provided above shall be paid for at the Contract rate for mobilization of equipment, labour and materials. The price and payment shall be full compensation for mobilizing equipment, labour and materials necessary to complete the work.

Pay items shall be:

08/10/01	Mobilization for deck slab repairing work etc	Square Metre

8.11 Concrete Kilometre Posts

8.11.1 Description

This work shall consist of furnishing and installation of concrete kilometre posts as detailed on the Drawings and at locations indicated on the Drawings or as directed by the Engineer.

8.11.2 Materials

Concrete kilometre posts shall be precast using concrete conforming to the requirements of Section 5.1. Reinforcement steel shall conform to the requirements of Section 5.2. Paint, if indicated on the Drawings, shall be of the appropriate type and colour and to the approval of the Engineer.

8.11.3 Construction Methods

Construction, fabrication and installation of concrete kilometre posts shall be as shown on the Drawings.

8.11.4 Measurement

The quantity measured for payment shall be the actual number of concrete kilometre posts placed and accepted.

8.11.5 Payment

This work measured as provided above shall be paid for at the Contract rate for each monument and post. The price and payment shall be full compensation for furnishing and placing, including all materials, labour, equipment, tools, and incidentals necessary to complete the work.

Pay items shall be:

08/11/01	Concrete Kilometre Posts	Number

8.12 RCC Palisading

8.12.1 Description

This work shall consist of furnishing and placing Precast RCC posts with-

- (i) Precast RCC Plates/Planks with necessary anchoring with the RCC Posts;
- (ii) Cast in situ RCC Grade Beam and vertical wall constructed on the RCC Posts.

In accordance with the Specifications and in conformity with the requirements of the Drawing or as with other parts of the Contract Documents.

The RCC posts consist essentially of precast and driven "I" shaped RCC concrete posts laterally supporting the precast concrete plate or the cast in situ RCC wall with Grade Beam constructed on the driven RCC Posts.

8.12.2 Materials

The RCC posts, Grade Beam and RCC wall shall conform to the requirements of Section 4.2.2 and shall be constructed in accordance with the details shown on the Drawings, and with Sections 5.1 and 5.2.

The precast concrete plate shall be constructed in accordance with the details shown on the Drawings, and with Sections 5.1 and 5.2.

Cement to be used shall be type 1.

8.12.3 Construction Methods

8.12.3.1 RCC Post

All production and construction methods for RCC Posts shall conform to Sections 4.2.3 and 4.2.4 except that load testing shall not normally be required. For RCC Plate Palisading, the RCC Posts shall be driven by a monkey/drop hammer or by wash boring, whichever is suitable to site condition, up to the required depth as per proper grade, alignment and the approved drawing.

The Precast RCC Posts shall be driven by a monkey/drop hammer or by wash boring, whichever is suitable, in full length of the Posts as per proper grade, alignment and the approved drawing.

8.12.3.2 RCC Grade Beam

Construction methods for RCC Grade Beam shall conform to Sections 4.2.3 and 4.2.4.

The grade beam shall be constructed on the pre-cast driven RCC Posts by breaking the heads of the RCC Posts driven to the ground up to 150mm depth, scraping and removing loose

particles, placing reinforcement with necessary scaffolding, shuttering and then casting the Grade Beams in situ as per proper grade, alignment and the approved drawing.

8.12.3.3 RCC Vertical Wall

Construction methods for RCC vertical wall shall conform to Sections 4.2.3 and 4.2.4

The RCC vertical wall shall be constructed on the RCC Grade Beam supported by pre-cast driven RCC Posts after placing reinforcement, scaffolding, shuttering and then casting the vertical RCC wall up to the designed height as per proper grade, alignment and the approved drawing.

8.12.3.4 Precast RCC Plate/Planks

The precast concrete Plate/Planks shall be constructed in accordance with the Drawing, and Sections 5.1 and 5.2.

The precast plates/planks shall be placed between the RCC posts as shown on the Drawings. The planks shall be excavated or driven down to the levels indicated on the Drawings or as otherwise directed. In this connection it may be necessary to clear up the bed to the prescribed level and make local excavations along the planks as they are lowered. The method of placing the plates/planks and anchoring them with the RCC Posts shall comply in all respect as per the approved drawing, specification and direction of the Engineer.

8.12.4 Tolerances

The horizontal position of the RCC posts after being driven shall not deviate from the correct position more than ± 10 mm perpendicular to the line of the wall and ± 10 mm in the direction of the wall. The precast planks in between the piles are designed to allow for a longitudinal tolerance of RCC post position of ± 10 mm. If the Contractor during construction establishes that the above tolerance is too small, the Engineer may accept minor changes in the tolerance. Such changes will require corresponding changes in plank sizes.

8.12.5 Measurement

The unit of measurement shall be the linear meter of Palisading work completed as per the approved drawing and accepted by the Engineer in all respect.

8.12.6 Payment

The work shall be measured as provided above and shall be paid at the contract unit rate per linear meter. The rate shall constitute full compensation for all materials, labours, tools, equipment, driving, fitting, fixing fabricating, shuttering, casting, curing and all other incidental charges.

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No payments shall be made for unauthorized or unsatisfactory works

08/12/01(a)	RCC Palisading (4m post, 200mm X 200mm) with precast RCC Plate/Plank	Lin. Meter
08/12/01(b)	RCC Palisading (3m post, 150mm X 150mm) with precast RCC Plate/Plank	Lin. Meter
08/12/01(c)	RCC Palisading (2.67m post, 200mm X 200mm) with cast in situ vertical wall	Lin. Meter
08/12/01(d)	RCC Palisading (2m post, 150mm X 150mm) with cast in situ vertical wall	Lin. Meter

