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Ministry of Road Transport and Bridges
Roads and Highways Department

STANDARD TENDER DOCUMENTS

SECTION-7

GENERAL SPECIFICATIONS
(TECHNICAL SPECIFICATIONS)

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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 Engineers 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 (browsers) 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 AASTO 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

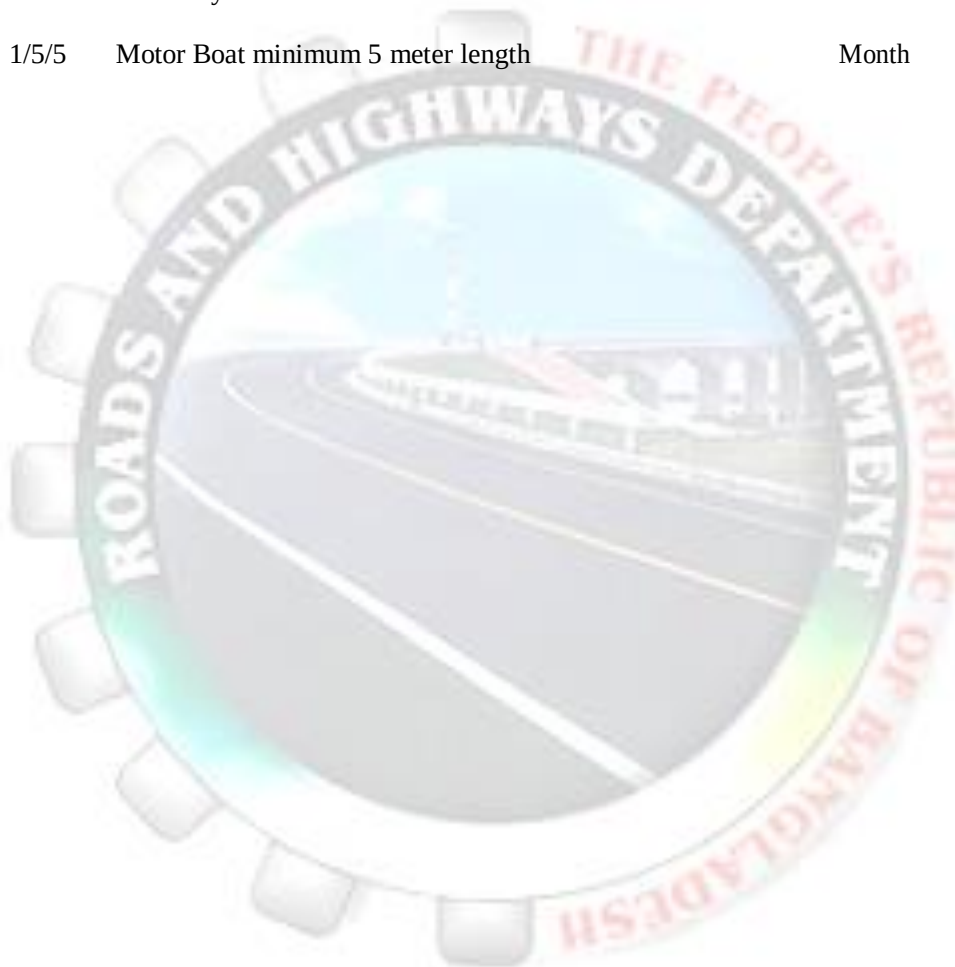
The Contractor's monthly rate for the provision and maintenance of vehicles and motor cycles shall include fuel, servicing, maintenance, drivers' wages, taxes, duties, registration, insurance, etc., as applicable under the current law of the Government of Bangladesh.

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.





DIVISION 2 EARTHWORK

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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 obtrude 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 layer below 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 Excavation of pavement by Milling Process

During pavement reclamation or maintenance existing pavement can be excavated using milling machine. Milling is the control removal method of an existing pavement to a desired depth, using specially designed equipment having replaceable tungsten carbide cutting teeth mounted on a rotor drum driven by the power supplied by the milling machine.

Important aspects in cold milling are the depth of milling, appropriate milling tools to govern the size of milled material, control of dust, collection and transportation of milled material, and stockpiling. Milling processes should be closely examined to make sure that the milled material is not contaminated with soil, base material, paving geotextiles, or other debris. The milled surface should also be inspected for “scabbing,” where thin, weakly bonded layers are left in place. If this is observed, the milling depth should be adjusted to remove the scab layer because, if allowed to remain in place, the performance of overlay will be poor. The milled surface should be inspected for uniform texture.

The finished milled surface shall be within 6-8 mm of a true profile grade both in transverse and longitudinal directions. If the milled surface is to be the final surface of the pavement, it should have either continuous or intermittent striations or any other pre-approved pattern which will provide an acceptable level of skid resistance. If pavement is to be constructed over the milled surface, it shall have a texture which will provide good bonding. The final gradation required of the reclaimed bituminous materials (RBM) by milling can be obtained by controlling depth of milling cut, and speed of machine.

2.2.3.g 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.h 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.i 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 Pavement by Milling	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 a 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.

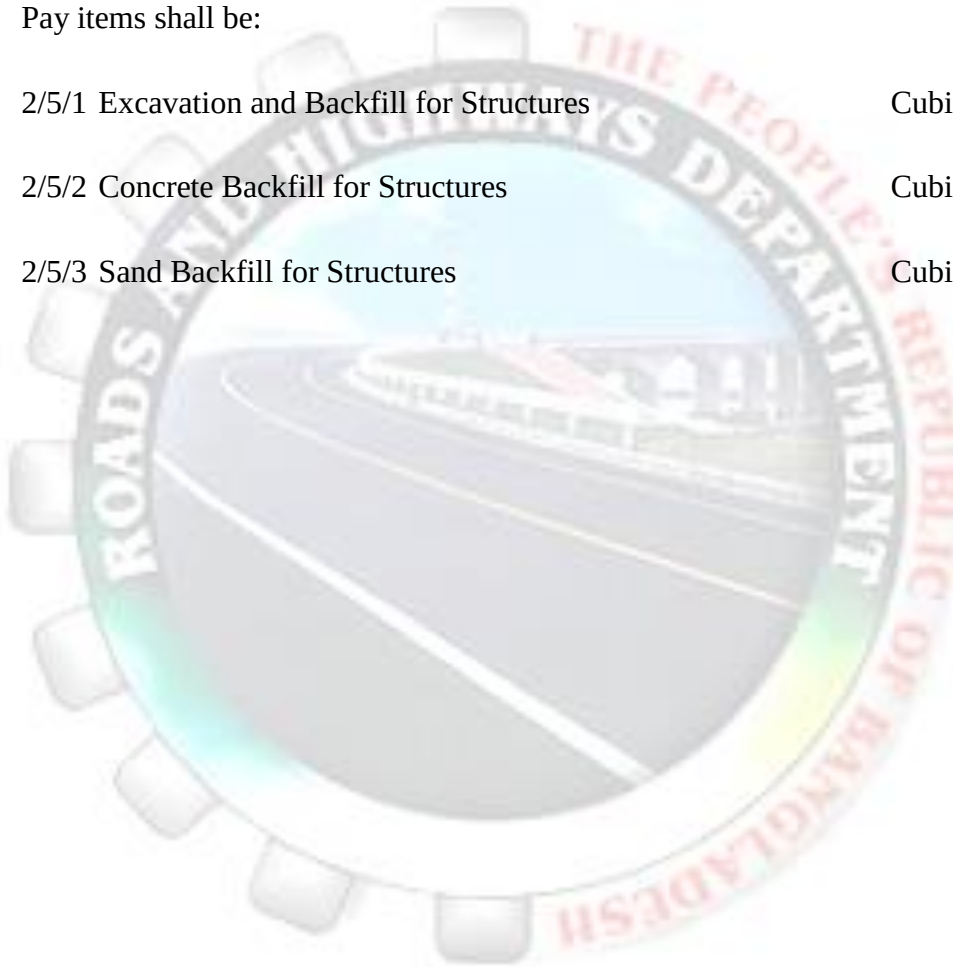
Payment for backfilling shall be included in the pay item for "Excavation and Backfill for Structures" except for sand backfill and concrete backfill. These backfill types shall be measured as provided in Section 2.5.4 and paid for at the concerned Contract unit prices, but no compensation in the pay 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 200 mm in thickness** on completion of 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

2.7 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	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 ± 10 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.

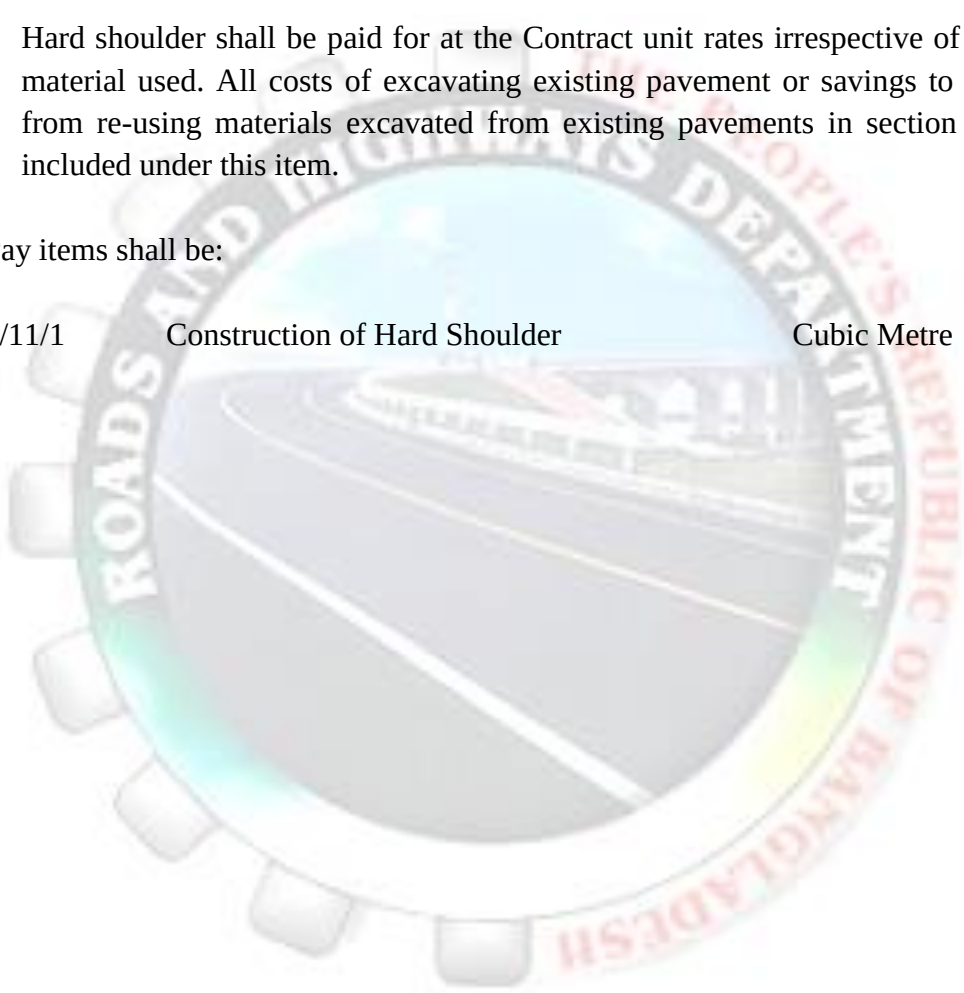
2.11.5 Payment

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

1. 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:
2. Using geosynthetic drains (Prefabricated Vertical Drain (PVD) with surcharge to achieve 90% consolidation of sub-soil within a prescribed time Stone/Sand columns.
3. Sand drain

2.13.2 STEEL SHEET PILES

2.13.2.1 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.

2.13.2.2 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.

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 specified otherwise, all steel for sheet piles shall be manufactured to ASTM, AISI, GB, JIS, DIN, BS or any other equivalent standards

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.

iv) 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.

2.13.2.3 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.

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 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.

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. He shall supply details with his tender of the brand and properties of the clutch sealant he plans to use.

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 2.13-1. Dimensional Tolerances for Steel Sheet Pile

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

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) Durability and Protection

All work associated with surface preparation and coating shall be undertaken inside a waterproof structure.

xi) 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.

2.13.2.4 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. 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
2/13/1	Setting Sheet Piles	Tonne
2/13/2	Setting Sheet Piles (Re-used)	Tonne

2.13.3 PRE-FABRICATED VERTICAL DRAIN (PVD)

The following section will replace section 2.13.2 of the draft specification of RHD.

2.13.3.1 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.

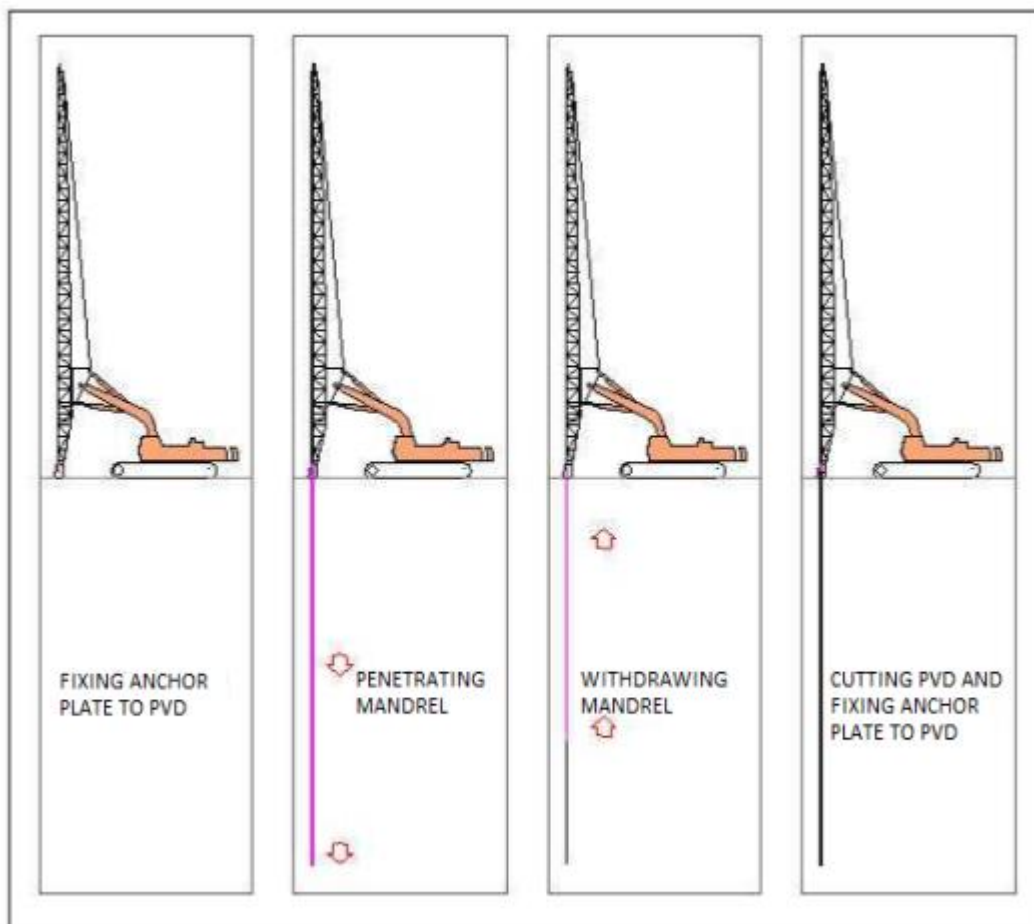


Figure 13-1. PVD installation process

2.13.3.2 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 2.13-2. Geometric properties of drain

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

Table 2.13-3. 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)		< 24	

Property	Test Method	Proposed Values	Remarks
Size of Clay)			
*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 2.13-4. Gradation of Granular Sand Blanket

Sieve Designation	Present 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.

2.13.3.3 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

- 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.
- 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.
- 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.
- 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

- 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.
- 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.
- 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.

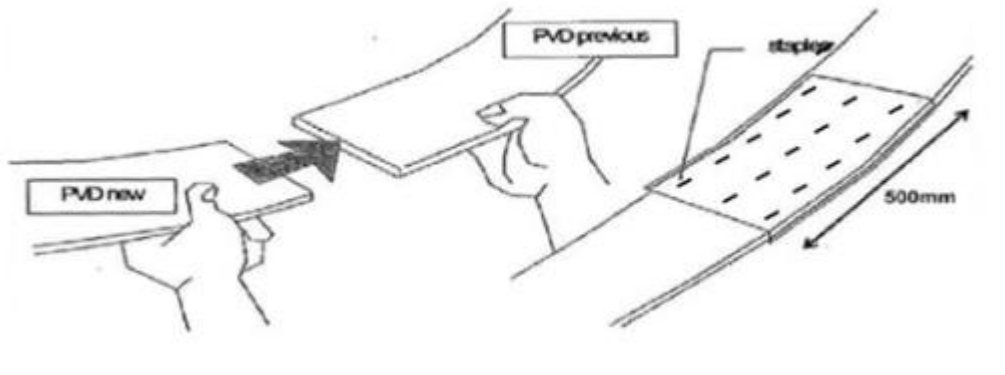


Figure 13-1. PVD overlapping

- 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.

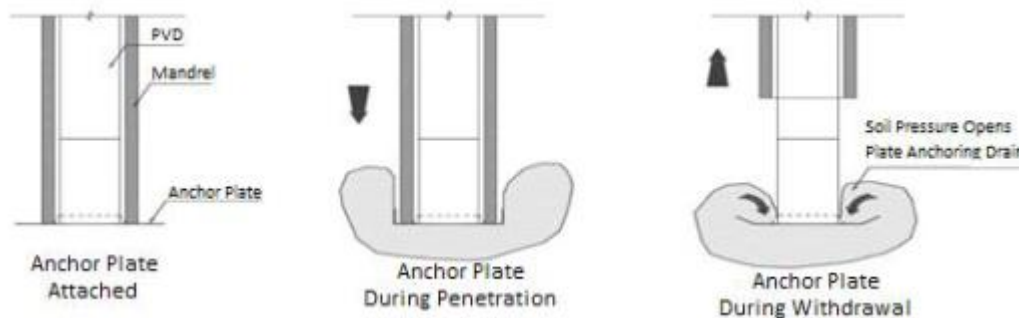


Figure 13-2. Anchor plate at the end of PVD

- 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.

2.13.3.4 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	Prefabricated Vertical Drains	Lin meter
2/13/4	Geo-textile fabric – separation (non-woven)	Square meter
2/13/5	Geo-textile fabric – high strength one way (woven)	Square meter
2/13/6	Geo-textile fabric – high strength two way (woven)	Square meter
2/13/7	Granular drainage blanket.	Cubic meter
2/13/8	Settlement measuring instrument including plate, settlement pin, Piezometer, Inclinator	Nos.

2/13/9	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.

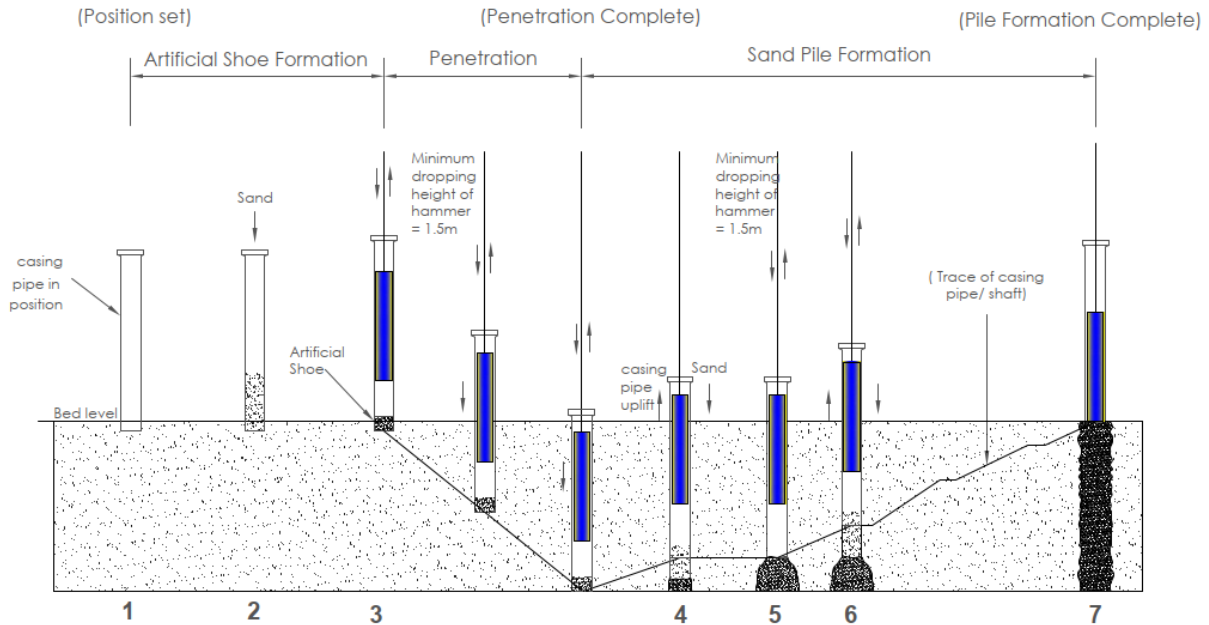


Figure 2.13-4. Procedure of Sand Compaction Pile

2.13.4.2 Materials

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

- 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.
- 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.
- 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 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
- 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
- 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
2/13/10	Execution of sand compaction pile through displacement method by using tripod rig, mechanical winch, drop hammer (minimum 1 ton), casing pipe up to a depth of 10m	Linear Meter

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.

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 and quality control.
- 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 2.14-1 : 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 1	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 2.14-3 : 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 4751/1S:14294-1995
<15	0.5	0.43
15 to 5	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 2.14-4 and 2.14-5.

Table 2.14-4 : 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 2.14-5 : 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 2.14-6 : 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 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 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 14-7.

2.14.3.b.3 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 14-7 : 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.4 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 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.2 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.3 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.

2/14/2	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 2.14-8. 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 ($\pm 5\%$)

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 ($\pm 10\%$)
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 10319 or equivalent	ISO or 8 kN/m (-2.0_
Static Puncture Resistance	EN 12236 or equivalent	ISO or 1400 N (-20%)
Dynamic Puncture Resistance	EN 13433 or equivalent	ISO or 33 mm (+15)
Flux perpendicular to plane	EN 11058 or equivalent	ISO or 100 l/(m ² .s) (+/- 30)
Apparent Opening Size, O ₉₀	EN 12956 or equivalent	ISO or 110 micron (+/- 50)
External Membrane	EN 10319 or equivalent	ISO or 16 kN/m (-2.0)
Mass per unit area	EN ISO 9864 or equivalent	ISO or 120 g/m ² (-10%)
Tensile strength	EN 10319 or equivalent	ISO or 16 kN/m (-2.0)
C) Drainage Core		
Mass per unit area* (This is not performance parameter)	EN ISO 9864 or equivalent	ISO or 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

Geocomposite 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

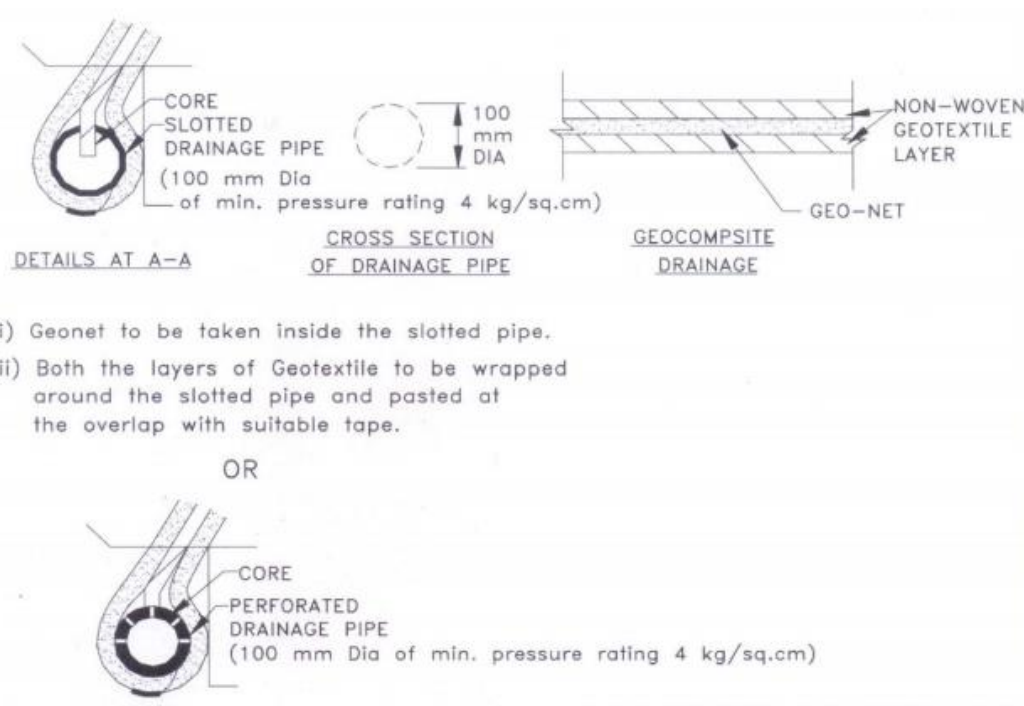


Figure 2.14-1. Details of Geotextile wrapping

- 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 2.14-9 : 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°) For slopes up to 80°	ASTM D 5035	KN/m	2
Ultraviolet stability at 500h, Retained strength percentage with respect to	ASTM D 4355	%	80

original strength			
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 (as detailed in the Drawings or as directed by the Engineer)	Square metres

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 2.14-12, when used for erosion control measures.

Table 2.14-11 : 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	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

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 or as directed by the Engineer)	Square metre

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 2.14-13.

Table 2.14-13: 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 2.14-14.

Table 2.14-14 : 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 Geogrids

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 2.14-15.

Table 2.14-15: Properties of Asphalt Reinforcement Geogrids

Property	Unit	Test Method	Requirement		
			Tensile strength in both MD and CD, Not less than		
Tensile strength	KN/m	ISO-10319	25	50	100
% Elongation at break	%	ISO-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 Square metre
 fibre geo grid (as detailed in the Drawings or
 as directed by the Engineer)

2.15 MSE (Mechanically Stabilized Earth) WALL FOR RAMP

2.15.1 Definition of MSE Wall

The work covers the construction of MSE wall structures, together with the construction of earthwork in layers, assembly and erection of reinforcing elements and placement of facing panels and all associated components.

Mechanically Stabilized Earth (MSE): An earth retaining structure comprising selected fill and soil reinforcement that is embedded at regular intervals in both vertical and horizontal directions within the fill to form a composite structure. The visible face of the MSE will be decorative or plain structural reinforcement concrete.

2.15.2 Design

Design Life Requirement:

The MSE (Mechanically Stabilized Earth) wall shall have a minimum design life of 75 years.

Design Procedures:

The design of the MSE wall shall conform to the AASHTO LRFD Bridge Design Specifications (2007), with 2008 and 2009 Interim Revisions.

The LRFD (Load and Resistance Factor Design) method in various forms is now being applied throughout the world. The Federal Highway Administration (FHWA) USA has adopted Mechanically Stabilized Earth Walls and Reinforced Slopes, Design and Construction Guidelines, by Elias et al. as their current guidelines for MSE wall design and construction.

MSE used in conjunction with a bridge element shall be independent of the bridge structure. Vertical and horizontal loads arising from the bridge shall be supported on piles. Piles shall be surrounded with a compressible material to ensure that horizontal loads arising from the MSE are not transmitted to the piles.

MSE walls for Bridge Ends (abutments) shall not be allowed. The MSE shall be designed to support dead and live loads arising from bridge approach roads including vertical and lateral loads, soil pressures, impact loads from barriers and guard fences and loads arising from signs and sign support structures.

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

Subsurface drainage which complies with the specification shall be provided within the MSE 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 MSE wall design are listed below:

Strength Limit States for MSE 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 MSE walls

External Stability

- Vertical wall movements
- Lateral wall Movements

Global Stability of MSE walls

- Overall Stability
- Compound Stability

In cases where specific design details for the MSE 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.

2.15.3 Material Requirements

The component materials of MSE Wall shall consist of the backfill material, MSE Wall concrete facing panels, reinforcing strips and other accessories.

2.15.3.a Reinforced Earth Fill

The backfill material used in the MSE Wall shall be crushed rock and crusher sand or coarse river sand (Sylhet Sand) free from organic or other deleterious material. The material shall conform to the physical, electrochemical and chemical properties detailed below:

The angle of internal friction of the granular fill under saturated condition shall not be less than 36° . The Plasticity Index as determined by AASHTO T 90 shall not exceed 6. The grading requirement of the material shall conform to that shown in the Table below:

Table 2.15-1: Grading Requirement of Earth fill material

Sieve Size mm	Percent passing
14	100
10	70-90
5	48-70
2.36	30-53
1.18	20-40
0.6	12-30
0.3	7-21

0.15	4-15
0.075	2-10

The material shall be substantially free of shale or other soft, poor-durability particles. The material shall have a magnesium sulphate soundness loss of less than 30 percent after four cycles, measured in accordance with AASHTOT – 104 or a sodium sulphate loss of less than 15 percent after five cycles determined in accordance with AASHTO T – 104. For metallic reinforcement Resistivity shall be more than 3000 ohm-cm (AASHTO T 288), PH shall be 5 – 10 (AASHTO T 289), Chlorides shall be less than 100 parts per million (AASHTO T 291), Sulphate shall be less than 200 parts per million (AASHTO T 290) and organic content shall be less than 1 percent (AASHTO T 267). For Geosynthetic reinforcement Polyolefin (PP and HDPE), pH shall be more than 3 (AASHTO T 289) and Polyester pH shall be more than 3 and less than 9.

2.15.3.a MSE Reinforcing Element

In the current design practices, the recommended length of soil reinforcement is 0.7 H (H is the height of wall) or not less than 2.4 m according to Federal Highway Administration (FHWA).

The reinforcing element shall be of geotextile, aluminum alloy strip, copper strip, carbon steel strip, mats of metal or synthetic grid, or any other proprietary material which may be approved by the Engineer and indicated on the drawings. Strips manufactured by Terre Armee is widely in use in MSE in Bangladesh and is recommended. Horizontal spacing of the strips can be 330 mm and vertical spacing can be 490 mm.

2.15.3.b MSE Wall Concrete Facing Panels

Only pre-cast reinforced concrete panels shall be used as facing. Size of the panel can be one metre by one metre, of thickness 140 cm. Connectors shall be of galvanized steel.

2.15.3.c.1 Concrete Quality and Strength

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

Characteristic compressive strength at 28 days	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.

2.15.3.c.2 Facing Finish and Tolerances

The finish of the exposed face of the panel shall be as shown in the drawings and shall be free of honeycombs, stains or deep cracks.

Tolerance in dimensions are as follows:

- (i) the height of full panels shall be within ± 5 mm while the height of half panels shall be within ± 3 mm.
- (ii) the width of all panels shall be within ± 5 mm
- (iii) the difference between the lengths of the diagonals shall not exceed 10 mm
- (iv) twist or warp shall not exceed 5 mm

2.15.3.d Joint Fillers

The fillers for the vertical and horizontal joints shall be flexible open cell polyurethane foam strips of 40 mm square cross section.

2.15.3.e Cushion Pad

The cushion pads placed at the horizontal joint shall be made of rubber with shore hardness 85.

2.15.3.f Measurement and Payment

The measurement for facing wall shall be in square meters. The measurement for crush barrier and Friction slab shall be in linear meters. Measurement for compacted earth fill shall be in cubic meters for compacted soil. Rate shall include cost of labor, plant hire, material storage, cost of labor for ground Improvement needed as per existing ground conditions and handling expenses for completing the works. Rate for providing reinforcement elements shall include material cost, all transportation costs and storage of the same, the rate shall also include cost of laying of reinforcing elements including all overlaps, jointing or stitching, heat bonded or extension. Rate for fascia fixing shall include cost of joints, all necessary temporary formworks, scaffolding and all lifts and lead if any, as shown in the drawing. Rate for bed block and capping beam shall include all items of excavation, concrete, reinforcing steel, formwork, labor and equipment. Rate for soil till shall include compaction as desired in requisite layers through mechanical means, cost of hire or labor for plant operations, dressing and levelling slopes, including special measures for edge reinforcement as shown in the drawing.

2/15/1	Furnishing and installing Mechanically Stabilized Earth (MSE) Wall for Ramp (as detailed in the Drawings or as directed by the Engineer)	Square metre
	Facing Wall	Square metre
	Engineering Material Fill between face walls	Cubic metre
	Crush Barriers and Friction Slabs	Metre





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 3.7 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 3.11.3.2, 3.11.3.3 and 3.9.3.4.

3.1.5 Levelling 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.

3.1.6 Payment

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 Recompact 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

The Contractor shall submit results of material tests on the proposed sub-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.

Material shall be natural or artificial aggregate material (crushed stone, crushed slag etc), 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 are 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. Recycled base or sub-base aggregates satisfying the specification requirements may also be used.

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 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).
- d) Los Angeles Abrasion Value:

In case of Stone aggregate, material when sampled and tested shall have a Los Angeles Abrasion Value not greater than 40% or Aggregate Crushing Value (ACV) not greater than 30%.

Sub-base layer can be divided into two parts, whereas the lower part can be used as sub-surface drainage layer or filter layer to serve the drainage purpose as proposed in the drawings and approved by the Engineer. 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 the grading requirements of the following table containing Grading D envelope ((Indian Specification of Subbase Envelope VI).

Table 3.2-1

Grading Requirements for Sub-base Material					
Sieve Size (mm)	Percentage by Weight Passing Sieves				
	Grading A	Grading C	Grading B	Grading D (Drainage cum Filter layer)	Tolerance for mix design
50	100	--	100	100	± 1
38	85 – 100	--	80 – 100	90 – 100	
20	55 – 95	100	70 – 90	70 – 95	± 6

10	35 – 75	70 – 100	55 – 90	55 – 75	± 7
5	25 – 60	45 - 85	35 – 65	30 – 55	± 6
2.4	15 – 50	30 – 70	25 – 55	10 – 25	
0.600	7 – 35	15 – 45	20 – 40	2 - 10	± 2
0.300	6 – 27	7 – 30	10 – 15	0 - 6	
0.075	3 – 15	4 - 20	<5	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 subbase.

3.2.3.3 Preparation of Mix

Mixed materials shall be prepared in an approved mixing plant of suitable capacity with a provision for controlled addition of water and mixing arrangement like pug-mill or pan type mixer of concrete batching plant.

While adding water, due allowance should be made for evaporation losses. However, at the time of compaction, water in the wet mix shall be the optimum value of moisture content. The mixed material should be uniformly wet and no segregation should be permitted.

The Engineer shall decide whether to utilize a batching plant or manual methods for laying the aggregate base on the road during preparation of estimate depending on project's value and importance.

3.2.3.4 Spreading of Mix

Immediately after mixing, the aggregates shall be spread uniformly and evenly upon the prepared sub-grade or improved subgrade in accordance with the layer depth, with an un-compacted thickness up to 150 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 may be spread by a paver finisher. 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 levelling control system with electronic sensing device to maintain mat thickness and cross slope of mat during laying procedure.

In exceptional cases where it is not possible for the paver to be utilized, 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.

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.

The Engineer may permit manual mixing and /or laying of sub-base mix depending upon the quantity of work or importance of the work.

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 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.

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/base course or sub-grade. 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 for the material. Static Deformation Modulus E_{v2} shall be 150 MPa and E_{v2}/E_{v1} shall be ≤ 2.3 as per 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 acceptable criteria but solely for record keeping purpose.

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.

Item shall be:

3/2/1 Sub-base

Cubic Metre

3.3 LIME TREATED SOIL FOR IMPROVED SUB-GRADE/SUB-BASE

3.3.1 Scope

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 15%.

3.3.2 Materials

Soil:

Except when otherwise specified, the soil used for stabilisation shall be the local clayey soil having a plasticity index greater than 8.

Lime:

Lime for lime-soil stabilisation 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.

Quantity of lime in stabilised mix:

Quantity of lime to be added as percentage by weight of the dry soil shall be as specified in the Contract. 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 Contract. 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 stabilisation shall be clean and free from injurious substances. Potable water shall be preferred.

3.3.3 Construction Methods

3.3.3.1 Weather limitations:

Lime-soil stabilisation shall not be done when the air temperature in the shade is less than 10 °C.

3.3.3.2 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.

3.3.3.3 Soil Pulverisation Requirements for Lime Stabilisation

3.3.3.4 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 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.

3.3.3.5 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 stabilised 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.

3.3.3.6 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.

3.3.3.7 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 colour reaction, when the treated material is tested with the standard phenolphthalein alcohol indicator, will be considered evidence of inadequate mixing.

3.3.3.8 Moisture content for compaction:

The moisture content at compaction to be determined by trial compaction at site.

3.3.3.9 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 centre, 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.

3.3.3.10 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.

3.3.4 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.

3.3.5 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be provided and maintained.

3.3.6 Measurements for Payment

Stabilised soil sub-base/ISG shall be measured as finished work in position in cubic metres.

3.3.7 Payment

Sub-base shall be paid for at the contract unit rate irrespective of the sources of materials used for constructing the sub-base.

Pay items shall be

3/3/1	Lime treated ISG	CubicMetres
3/3/2	Lime treated sub base	CubicMetres

3.4 CEMENT TREATED SUB-BASE/BASE

3.4.1 Scope

This work shall consist of laying and compacting a sub-base/base course of sand treated with cement on prepared 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:

3.4.2 Methodology

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 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.

The Cement Treated Sub Base/Base can be engineered to behave like a granular base course, minimizing the risk of cracking and ensuring long-term performance of the pavement structure following the steps properly.

3.4.3 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 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. If the material passing 425 micron sieve is plastic, it shall have a liquid limit not greater than 45 percent and a plasticity index not greater than 20 percent determined in accordance with STP.

Cement:

Cement for stabilisation shall either be ordinary portland cement, portland slag cement or Portland-puzzolana cement.

Table 3.4-1: Grading Limits of Material for Stabilisation with Cement

Sieve size	Percentage by mass passing
	Sub-Base/Base Within the range
50.00 mm	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

Quantity of cement in stabilised mix:

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 clause of Contract.

Water:

The water to be used for cement stabilisation shall be clean and free from injurious substances. Potable water shall be preferred.

3.4.4 Construction Methods**3.4.4.1 Weather limitations**

Stabilisation shall not be done when the air temperature in the shade is less than 10°C.

3.4.4.2 Degree of pulverisation:

For stabilisation, the soil before addition of stabilizer, shall be pulverised, where necessary.

3.4.4.3 Moisture content for compaction:

The moisture content at compaction to be determined by trial at site.

3.4.4.4 Rolling:

Care shall be taken to see that the compaction of cement stabilised material is completed within initial setting time of cement used or period as instructed by Engineer in dry weather.

3.4.4.5 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.

3.4.5 Strength

Cement treated soil 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. The extra pavement thickness needed on account of lower UCS shall be constructed by the Contractor at his own cost.

3.4.6 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be provided and maintained.

3.4.7 Measurements for Payment

Stabilised soil sub-base/base shall be measured as finished work in position in cubic metres.

3.4.8 Payment

Cement treated Sub-base/ Base shall be paid as cubic meters.

Pay items shall be

3/4/1	Cement treated sub base	CubicMetres
3/4/2	Cement treated base	CubicMetres

3.5 WATER BOUND MACADAM SUB-BASE/BASE

3.5.1 Scope

This work shall consist of clean crushed aggregates mechanically interlocked by rolling and bonding together with screening, binding material where necessary and water laid on a properly prepared subgrade/sub-base/base or existing pavement, as the case may be and finished in accordance with the requirements of these Specifications and in close conformity with the lines, grades, cross-sections and thickness as per approved plans or as directed by the Engineer. This specification is meant for repairs and minor works of widening nature, and also at locations where it is not feasible to lay WMM.

3.5.2 Materials

Coarse aggregates:

Coarse aggregates shall be either crushed or broken stone, crushed slag or any other naturally occurring aggregates such as kankar and laterite of suitable quality. Materials other than crushed or broken stone and crushed slag shall be used in sub-base courses only. If crushed gravel /shingle is used, not less than 90 percent by weight of the gravel/shingle pieces retained on 4.75 mm sieve shall have at least two fractured faces. The aggregates shall conform to the physical requirements set forth in Table 3.5-1. The type and size range of the aggregate shall be specified in the Contract or shall be as specified by the Engineer. If the water absorption value of the coarse aggregate is greater than 2 percent, the soundness test shall be carried out on the material delivered to site.

Table 3.5-1 Physical Requirements of Coarse Aggregates for Water Bound Macadam for Sub- base/Base Courses.

Test	Requirements
Los Angeles Abrasion value	40 percent (Max)
Aggregate Impact value	30 percent (Max)
Combined Flakiness and Elongation Index (Total)	40 percent (Max)

The requirement of flakiness index and elongation index shall be enforced only in the case of crushed broken stone and crushed slag.

Crushed or broken stone:

The crushed or broken stone shall be hard, durable and free from excess flat, elongated, soft and disintegrated particles, dirt and other deleterious material.

Crushed slag:

Crushed slag shall be made from air-cooled blast furnace slag. It shall be of angular shape, reasonably uniform in quality and density and generally free from thin, elongated and soft pieces, dirt or other deleterious materials. The weight of crushed slag shall not be less than 11.2 kN per m^3 and the percentage of glossy material shall not be more than 20. It should also comply with the following requirements:

- i) Chemical stability
- ii) Sulphur content
- iii) Water absorption

Grading requirement of coarse aggregates:

The coarse aggregates shall conform to one of the gradings given as specified, provided in previous

3.5.3 Screenings:

Screenings to fill voids in the coarse aggregate shall generally consist of the same material as the coarse aggregate. However, where permitted, predominantly non-plastic material such as moorum or gravel (other than rounded river borne material) may be used for this purpose provided liquid limit and plasticity index of such material are below 20 and 6 respectively and fraction passing 75 micron sieve does not exceed 10 percent.

The use of screenings shall be omitted in the case of soft aggregates such as brick metal, kankar, laterites, etc. as they are likely to get crushed to a certain extent under rollers.

3.5.4 Binding material

Binding material to be used for water bound macadam as a filler material meant for preventing raveling shall comprise of a suitable material approved by the Engineer having a Plasticity Index (PI) value of less than 6.

The quantity of binding material where it is to be used, will depend on the type of screenings. Generally, the quantity required for 75 mm compacted thickness of water bound macadam will be $0.06\text{--}0.09 \text{ m}^3$ per 10 m^2 .

Application of binding materials may not be necessary when the screenings used are of crushable type such as moorum or gravel.

3.5.5 Construction Operations**Preparation of base**

The surface of the sub-grade/sub-base/base to receive the water bound macadam course shall be prepared to the specified grade and camber and cleaned of dust, dirt and other extraneous material. Any ruts or soft yielding places shall be corrected in an approved manner and rolled until firm surface is obtained.

Where the WBM is to be laid on an existing metaled road, damaged area including depressions and potholes shall be repaired and made good with the suitable material. The existing surface shall be scarified and re-shaped to the required grade and camber before spreading the coarse aggregate for WBM.

As far as possible, laying water bound macadam course over existing bituminous layer may be avoided since it will cause problems of internal drainage of the pavement at the interface of two courses. It is desirable to completely pick out the existing thin bituminous wearing course where water bound macadam is proposed to be laid over it.

3.5.6 Measurements

Stabilised soil sub-base/base shall be measured as finished work in position in cubic metres.

3.5.7 Payment

Sub-base shall be paid for at the contract unit rate irrespective of the sources of materials used for constructing the sub-base.

Pay items shall be

3/5/1	Water bound macadam sub base	CubicMetres
3/5/2	Water bound macadam cement treated base	CubicMetres

3.6 AGGREGATE BASE

3.6.1 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.

3.6.2 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, and crushed and screened to achieve the required grading. 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 order of the Engineer.

The material for base shall conform to the requirements given below:

a) Grading. The grading shall conform to one of the grading envelopes A or B, of Table 3.7-2. The material shall be well graded within the envelope with no excess or deficiency of any size. The grading shall conform to grading envelope A of Table 3.7-2 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 Crushing Values (ACV) and Los Angeles Abrasion Value (LAA) as the following table.

Table 3.6-1:

Type of Base	ACV (%)	Los Angeles Abrasion Value (%)
Base Type-I	Less than 25%	Less than or equal 30%
Base Type-II	Less than 30% TPF> 150 kN	Less than or equal 40%

Table 3.6-2:

Grading Requirements for Base Material			
Sieve Size (mm)	Percentage by Weight Passing Sieves		Tolerance for mix design
	Grading A	Grading B	

50	100	--	± 1
38	90 – 100	--	
20	50 – 85	100	± 6
10	30 – 65	80 – 100	± 7
5	25 – 50	50 – 80	± 6
2.4	15 – 38	35 – 65	
0.600	8 – 22	15 – 40	± 2
0.300	6 – 16	10 – 30	
0.075	2 – 8	5 – 10	± 1

3.6.3 Construction Methods

3.6.3.1 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.

3.6.3.2 Provision of Lateral Confinement of Aggregates

While constructing wet mix macadam, arrangement shall be made for the lateral Confinement of wet mix. This shall be done by laying materials in adjoining shoulders along with that of wet mix.

3.6.3.3 Preparation of Mix

Wet Mix Macadam 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.

3.6.3.4 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.

The mix may be spread by a paver finisher. The paver finisher shall be self-propelled of adequate capacity with following features:

- iv) 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.
- v) Hydraulically operated telescopic screed for paving width upto to 8.5m and fixed screed beyond this. The screed shall have tamping and vibrating arrangement for initial compaction of the layer.
- vi) Automatic levelling control system with electronic sensing device to maintain mat thickness and cross slope of mat during laying procedure.

In exceptional cases where it is not possible for the paver to be utilized, 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.

The Engineer may permit manual mixing and /or laying of wet mix macadam where small quantity of wet mix macadam is to be executed. Manual mixing/laying in inaccessible/ remote Locations and in situations where use of machinery is not feasible can also be permitted. Where manual mixing/laying is intended to be used, the same shall be done with the approval of the Engineer.

3.6.3.5 Compaction

After the mix has been laid to the required thickness, grade and crossfall/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-grade is soft or yielding or when it causes a wave- like motion in the sub-base/base course or sub-grade. 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 crossfall. 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 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, Static Deformation Modulus E_{v2} shall be 180 MPa and E_{v2}/E_{v1} shall be ≤ 2.2 (Technical Standards including ASTM 1195/ASTM 1196 and DIN 18134). Testing for E_{v2} and E_{v1} is mandatory; however, it's important to note that the test results will not be used as acceptable criteria but solely for record keeping purpose.

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 the layer and recompacted.

3.6.3.6 Setting and Drying

After final compaction of wet mix macadam course, the road shall be allowed to dry for 24 hours.

3.6.4 Opening to Traffic

No Vehicular traffic shall be allowed on the finished wet mix macadam surface. Construction, equipment may be allowed with the approval of the Engineer.

3.6.5 Surface Tolerance

The finished surface of the aggregate base shall be checked for level and crossfall 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.

3.6.6 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 recompact. 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.

3.6.7 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.

3.6.8 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, 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.

Pay items shall be:

3/6/1 Aggregate Base Type I

Cubic Metre

3/6/2 Aggregate Base Type II

Cubic Metre

3.7 Geo-fabric Reinforced Seal (GRS) as Strain Alleviating Layer (SAMI)

3.7.1 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:

- a) Spraying a layer of bitumen (bond/tack coat) on to the existing surface
- b) Covering the bond coat with an approved fabric and lightly rolling to ensure good adhesion of the fabric
- c) Application of binder
- d) Spreading a sealing aggregate
- e) 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.

3.7.2 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 3.7-1 below.

Table 3.7-1: 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 3.13 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.

Stabilised Heavy Duty Pavements

For stabilised 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 more hungry in those areas.

3.7.3 Construction Method

3.7.3.1 General

Generally, construction method shall be as per Section 3.13.3 except where noted differently below.

3.7.3.2 Sequence of Operations

A typical order of operations is shown in Table 3.7-2. 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 3.7-2: 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

3.7.3.3 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 stabilised), 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.

3.7.3.4 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.

3.7.3.5 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 3.7-1 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.

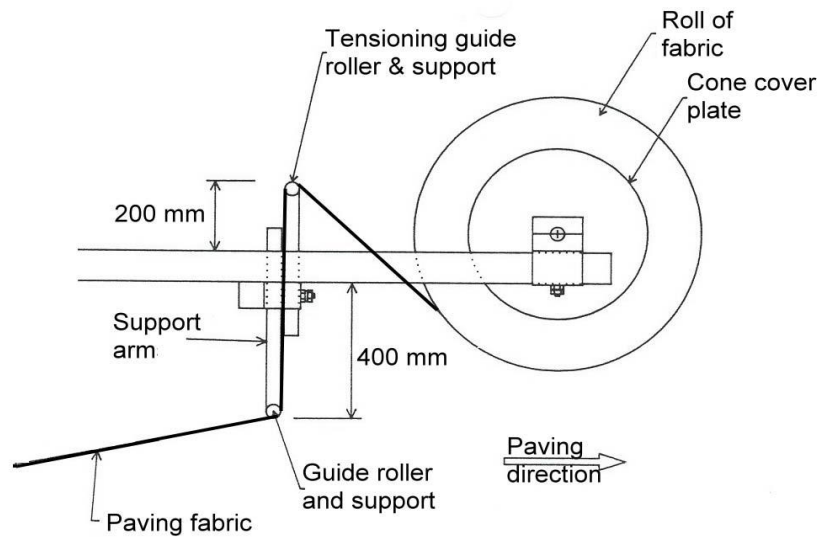


Figure 3.7-1: Schematic of a Fabric Spreader



3.7.3.6 Spraying

It is accepted practice that the edges of the geotextile are covered by the seal.

3.7.3.7 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.

3.7.3.8 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.

3.7.3.9 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 joint 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.

3.7.3.10 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

3.7.3.11 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.

3.7.3.12 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.

3.7.3.13 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.

3.7.4 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.

3.7.5 Measurement

The GRS SAMI 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.

3.7.6 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 and anti-stripping agent bitumen additive will not be paid for separately, and any costs involved should be included within pay item 3/3/1. Pre-coating of chippings shall be carried out without any additional payment.

Pay items shall be:

Pay Item No.	Description	Unit Measurement
3/7/1	Single GRS Surface Treatment	Square Metres
3/7/2	Bituminous Tack Coat (plant work)	Square Metres
3/7/3	Or Bituminous Tack Coat (labour intensive work)	Square Metres

3.8 BITUMINOUS MATERIALS

3.8.1 Description

This Section specifies the bituminous materials to be used in the work.

3.8.2 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.

3.8.2.1 Bitumen

3.8.2.1.1 Penetration Grade Bitumen

Bitumen shall 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.

As adjustments to ASTM D946 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 48-56 (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 3.8-1: ASTM D946 Specification for Penetration Grade Bitumen with adjustments

	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 [77 °F], 100 g, 5 s	40	50	60	70	85	100	120	150	200	300
Softening Point, °C [°F]	49 [120]		46 [115]		42 [108]		38 [100]		32 [90]	
Flash point, °C [°F], (Cleveland open cup)	230 [450]	...	230 [450]	...	230 [450]	...	220 [425]	...	175 [350]	...
Ductility at 25 °C [77 °F], 5 cm/min, cm	100	...	100	...	100	...	100	...	100 ^A	...
Solubility, % ^B	99.0	...	99.0	...	99.0	...	99.0	...	99.0	...
Retained penetration after thin-film oven test, %	55+	...	52+	...	47+	...	42+	...	37+	...
Ductility at 25 °C [77 °F], 5 cm/min, cm after thin-film oven test ^C	...	...	50	...	75	...	100	...	100 ^A	...

^A If ductility at 25 °C [77 °F] is less than 100 cm, material will be accepted if ductility at 15 °C [60 °F] is 100 cm minimum at the pull rate of 5 cm/min.

^B Use Test Method D2042 or D7553.

^C 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.

Following ASTM test procedures should be maintained for measurement of above-mentioned values.

1. Sampling—Practice ASTM D140/D140M.
2. Penetration—Test Method ASTM D5/D5M (same as AASHTO T49)
3. Softening Point—Test Method ASTM D36/D36M.
4. Flash Point—Test Method ASTM D92.
5. Ductility—Test Method ASTM D113.
6. Thin Film Oven Test—Test Method D1754/D1754M OR Rolling Thin Film Oven Test—Test Method D2872
7. Solubility in Trichloroethylene—Test Method D2042 OR Solubility in N-Propyl Bromide—Test Method D7553

3.8.2.1.2 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). For 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 3.8-2: 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. %					

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 ASTM test procedures should be followed for measurement of above-mentioned values:

1. D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
2. D140/D140M Practice for Sampling Asphalt Materials
3. D2042 Test Method for Solubility of Asphalt Materials in Trichloroethylene
4. D2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
5. D4402/D4402M Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer
6. D6373 Specification for Performance-Graded Asphalt Binder

7. D6521 Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
8. D6648 Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
9. D7175 Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer
10. D7405 Test Method for Multiple Stress Creep and Recovery (MSCR) of Asphalt Binder Using a Dynamic Shear Rheometer

3.8.2.1.3 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 In 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 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, $^{\circ}\text{C} = \max 2.2$. (ASTM D7173)

Table 3.8-3: 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 ($^{\circ}\text{C}$)	< 58	< 64	< 70	< 76	< 82
Minimum pavement design temperature ($^{\circ}\text{C}$)	> -16	> -10	> -10	> -10	> -10
Original binder					
Flash-point temperature, D92; min. ($^{\circ}\text{C}$)	230	230	230	230	230
Viscosity, D 4402: max. $3 \text{ Pa} \times \text{s}$, test temperature ($^{\circ}\text{C}$)	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. %					
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. D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
2. D140/D140M Practice for Sampling Asphalt Materials
3. D2042 Test Method for Solubility of Asphalt Materials in Trichloroethylene
4. D2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)

5. D4402/D4402M Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer
6. D6373 Specification for Performance-Graded Asphalt Binder
7. D6521 Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
8. D6648 Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
9. D7175 Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer
10. D7405 Test Method for Multiple Stress Creep and Recovery (MSCR) of Asphalt Binder Using a Dynamic Shear Rheometer

In absence of available 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 3.8-4: ASTM D 5976 Specification for Polymer Modified Bitumen (In absence of DSR)

Designation	I-A		I-B		I-C		I-D	
	min	max	min	max	min	max	min	max
Penetration, 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		5000	
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)
Tests on RTFOT Residue ^b								
Elastic recovery, 25°C (77°F), 10 cm elongation, %	60		60		60		60	
Penetration, 4°C (39.2°F), 200 g, 60 s, dmm	20		15		13		10	

^aThe 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.

^bThe thin film oven test may be used, but the rolling thin film test shall be the referee method.

Following ASTM test procedures should be followed for measurement of above-mentioned values:

1. D 5 Test Method for Penetration of Bituminous Materials
2. D 36 Test Method for Softening Point of Bitumen (Ring and-Ball Apparatus)
3. D 92 Test Method for Flash and Fire Points by Cleveland Open Cup
4. D 113 Test Method for Ductility of Bituminous Materials
5. D 140 Practice for Sampling Bituminous Materials
6. D 1754 Test Method for Effect of Heat and Air on Asphaltic Materials (Thin-Film Oven Test)
7. D 2042 Test Method for Solubility of Asphalt Materials in Trichloroethylene
8. D 2170 Test Method for Kinematic Viscosity of Asphalts (Bitumens)
9. D 2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
10. D 4957 Test Method for Apparent Viscosity of Asphalt Emulsion Residues and Non-Newtonian Bitumens by Vacuum Capillary Viscometer
11. D 6084 Test Method for Elastic Recovery of Bituminous Materials by Ductilometer

2.8.2.1.4 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.

2.8.2.1.5 Cut-Back Bitumen

Three types of cutback bitumen will be used for RHD usage. 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 3.8-5: ASTM D2028 Specification for Rapid Curing Cutback Asphalt

TABLE 1 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 [374°F]	10	...	...	...	...	...	...	...
to 225°C [437°F]	50	...	35	...	15	...	...	...
to 260°C [500°F]	70	...	60	...	45	...	25	...
to 316°C [600°F]	85	...	80	...	75	...	70	...
Residue from distillation to 360°C [680°F], percent volume by difference	55	...	65	...	75	...	80	...
Tests on residue from distillation:								
Viscosity at 60°C [140°F], Pa · s ^A	60	240	60	240	60	240	60	240
Ductility at 25°C [77°F], 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 Rapid Curing Cutback Bitumen.

Table 3.8-6: ASTM D2027 Specification for Medium Curing Cutback Asphalt

TABLE 1 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: 5 s at 25 °C [77 °F] of 120 to 300 for Grades MC-30, MC-70, and 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 Rapid 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 3.8-7: ASTM D2026 Specification for Slow Curing Cutback asphalt

TABLE 1 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	10 000	2000	16 000	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

3.8.2.1.5 Emulsified Bitumen:

Catanionic and anionic emulsion can be used by RHD. 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 8: ASTM D2397 Specification

TABLE 1 Requirements for Cationic Emulsified Asphalt

NOTE 1—CQS-1h emulsions shall meet the requirements outlined in Practices D3910.

NOTE 2—CQS-1h is used for quick-set slurry seal systems.

NOTE 3—For viscosity, specify either Test Method D7226 or D7496.

NOTE 4—Specify either ash content (Test Method D8078) or solubility (Test Method D2042 or D7553).

Type Grade	Rapid-Setting				Medium-Setting				Slow-Setting				Quick-Setting	
	CRS-1		CRS-2		CMS-2		CMS-2h		CSS-1		CSS-1h		CQS-1h	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max
<i>Tests on Emulsified Asphalts:</i>														
Viscosity, Saybolt Furol at 25 °C [77 °F] SFS									20	100	20	100	20	100
Viscosity, Saybolt Furol 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											
<i>Coating ability and water resistance:</i>														
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, % ^A		0.10		0.10		0.10		0.10		0.10		0.10		0.10
Cement mixing test, %										2.0		2.0		N/A
<i>Distillation:</i>														
Oil distillate, by volume of emulsion, %		3		3		12		12						
Residue, %	60		65		65		65		57		57		57	
<i>Tests on Residue from Distillation Test:</i>														
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 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 Residues

Anionic Emulsion:

ASTM D977 specification will be followed for categorization of Anionic Emulsified Asphalt as shown in the following table.

Table 9: ASTM D2028 Specification

TABLE 1 Requirements for Emulsified Asphalt

Note 1—QS-1h emulsions shall meet the requirements outlined in Practices D3910.

Note 2—QS-1h is used for quick-set slurry seal systems.

Note 3—For viscosity, specify either Test Method D7226 or D7496.

Note 4—Specify either ash content (Test Method D8078) or solubility tests (Test Method D2042 or D7553).

Type	Rapid-Setting				Medium-Setting				MS-1				MS-2				MS-2h			
	RS-1		RS-2		HFRS-2		MS-1		MS-2		MS-2h		MS-2		MS-2h		MS-2h		MS-2h	
Grade	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Tests on Emulsified Asphalts:																				
Viscosity, Saybolt Furol at 25 °C SFS	20	100	...	...	...	...	20	100	100	...	100	...	...	...	...	...	...	...	...	...
Viscosity, Saybolt Furol at 50 °C SFS	...	...	75	400	75	400	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Viscosity, Rotational Paddle at 25 °C, mPa s	45	220	...	...	...	...	45	220	220	...	220	...	...	...	...	...	...	...	...	...
Viscosity, Rotational Paddle at 50 °C, mPa s	...	...	165	880	165	880	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Storage stability test, 24 h, % ^A	...	1	...	1	...	1	...	1	...	1	...	1	...	1	...	1	...	1	...	1
Demulsibility, 35 mL, 0.02 N CaCl ₂ , %	60	...	60	...	60	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Coating ability and water resistance:																				
Coating, dry aggregate	...	...	...	...	...	...	good	fair	good	fair	good	fair	good	fair	good	fair	good	fair	good	fair
Coating, after spraying	...	...	...	...	...	...	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair
Coating, wet aggregate	...	...	...	...	...	...	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair
Coating, after spraying	...	...	...	...	...	...	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair	fair
Cement mixing test, %	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sieve test, % ^A	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10
Residue by distillation, %	55	...	63	...	63	...	55	...	65	...	65	...	65	...	65	...	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	100	200	100	200	40	90	...	...	...	...
Ductility, 25 °C, 5 cm/min, cm	40	...	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	...	97.5	...	...	...	...	...
Ash content, %	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0
Float test, 60 °C s	...	...	...	...	1200	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Type	Medium-Setting				HFMS-2s				SS-1				SS-1h				Quick-Setting			
	HFMS-1		HFMS-2		HFMS-2h		HFMS-2s		SS-1		SS-1h		SS-1h		SS-1h		QS-1h		QS-1h	
Grade	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Tests on Emulsified Asphalts:																				
Viscosity, Saybolt Furol at 25 °C SFS	20	100	100	...	100	...	50	...	20	100	20	100	20	100	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	45	220	45	220	45	220
Viscosity, Rotational Paddle at 50 °C, mPa s	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Storage stability test, 24 h, % ^A	...	1	...	1	...	1	...	1	...	1	...	1	...	1	...	1	...	1	...	1
Demulsibility, 35 mL, 0.02 N CaCl ₂ , %	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Coating ability and water resistance:																				
Coating, dry aggregate	good	fair	good	fair	good	fair	good	fair	...	...	...	...	...	...	...	...	...	...	...	...
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	...	2.0	...	2.0	...	...	...	...	N/A
Sieve test, % ^A	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10	...	0.10
Residue by distillation, %	55	...	65	...	65	...	65	...	57	...	57	...	57	...	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	40	90	40	90	40	90
Ductility, 25 °C, 5 cm/min, cm	40	...	40	...	40	...	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	...	97.5	...	97.5	...	97.5	...
Ash content, %	...	1.0	...	1.0	...	1.0	...	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

3.8.3 Measurement

Measurement of bituminous material shall be either in metric tons or in litres as indicated in the Contract Documents.

The measured quantity shall be the quantity theoretically required to comply with the Contract, or shall be the quantity used and accepted, whichever is the less.

3.8.4 Payment

This work shall be paid for as provided in the Section of the Specifications dealing with the work incorporating the bituminous material and shall be full compensation for complying with that Section of the Specifications as well as this Section.

3.9 GENERAL REQUIREMENTS FOR BITUMEN BOUND SURFACING (plant method)

3.9.1 Description

3.9.1.1 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 3.10 is for Prime Coats

Section 3.11 is for Tack Coats

Section 3.12 is for Primer Seal

Section 3.13 is for Bituminous Surface Treatment (Plant Method).

Section 3.14 is for Dense Bituminous Surfacing (Plant Method).

Section 3.15 is for Pre Mix Bituminous Surfacing (Manual 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.

3.9.1.2 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.

3.9.1.3 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.

3.9.1.4 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 3.10.3.2 and 3.10.3.4:-

Passing sieves 10 mm and larger.....	± 5%
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	± 15° C
Temperature of mixture at delivery on road	± 15° 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.

3.9.2 Materials

3.9.2.1 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 3.9-1:

S.No.	Name of Test	Testing Procedure	Wearing Course	Base Course
1	Aggregate Crushing Value (ACV) (%)	STP 7.7.1	Less than 20%	Less than 25%

2	Los Angeles Abrasion (LAA) (%)	AASHTO T96	Less than 20%	Less than 20%
3	Water absorption	STP 7.5.4	Not more than 2%	Not more than 2%
4	Soundness	AASHTO T104	Loss in weight (after 5 cycles) with Sodium Sulphate solution- not more than 10%	
5	Coating & Stripping Test	AASHTO T182	Min. 95% retained coating	

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 25%.

3.9.2.2 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 3.9.2.1. 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 maximum 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.

3.9.2.3 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. 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 3.9-2:

Sieve Designation	Percentage by Weight (STP 3.3)
0.600 mm	100

0.150 mm	95 – 100
0.075 mm	65 – 100

Mineral filler shall be considered to include any mineral dust naturally present in the bitumen.

Approval of sources of supply of mineral filler 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.

3.9.2.4 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 3.4. 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.

3.9.3 Construction

3.9.3.1 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.

3.9.3.2 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.

3.9.3.3 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.
- 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 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): -

$$\text{Mixing time in seconds} = \frac{\text{Pugmill dead capacity in kilograms}}{\text{Pugmill dead capacity in kilograms}}$$

- 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 3.5.3.4.

- 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.

3.9.3.4 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 3.5.3.3(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 3.5.3.3(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 or over such partial width as may be practicable. Bituminous mixture pavers conforming to the requirements of Section 3.9.3.3(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 tyred 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 tyred 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

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 20cm 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.

3.9.3.5 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, the recommended values/ranges for IRI is 1.75 – 2 m/km for rutting depth 9 – 10 mm and for cracks, Pavement Condition Rating (PCR) 75 – 80, it is measured on a scale 0 – 100, where 100 means newly paved road.

3.9.3.6 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.

3.9.4 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.

3.9.5 Payment

The work shall be paid for as provided in the respective Section for each type of bituminous layer.

3.10 BITUMINOUS PRIME COAT

3.10.1 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.

3.10.2 Materials

3.10.2.1 Bituminous Materials

Bituminous material shall be a MC 30 or MC 70 cut back bitumen and shall conform to the requirements of Section 3.12.2.2. The bituminous material shall be approved by the Engineer and may be prepared 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.

3.10.2.2 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.

3.10.3 Construction Methods

3.10.3.1 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.

3.10.3.2 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.

3.10.3.3 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.

3.10.3.4 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 3.4-6 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.

3.10.3 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.

3.10.4 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 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:

3/10/1(a) Bituminous Prime Coat (plant placed)	Square Metre
or	
3/10/1(b) Bituminous Prime Coat (hand placed)	Square Metre

3.11 BITUMINOUS TACK COAT

3.11.1 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.

3.11.2 Materials

Bituminous material shall be either 60/70 or 80/100 penetration grade bitumen, cut back bitumen RC 30, RC 70 cut back bitumen RC 30, RC 70, or rapid setting emulsion conforming to the requirements of Section 3.12.2.2 of these Specifications. The bituminous material shall be approved by the Engineer.

3.11.3 Construction Methods

3.11.3.1 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 3.6, Bituminous Prime Coat.

3.11.3.2 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.

3.11.3.3 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 3.4-6 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.

3.11.4 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.

3.11.5 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:

3/11/1(a) Bituminous Tack Coat (plant work) Square Metre

or

3/11/1(b) Bituminous Tack Coat (labour intensive work) Square Metre

3.12 PRIMER SEAL

3.12.1 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.

3.12.2 Materials

3.12.2.1 Bituminous Material

Cutback bitumen conforming to the requirements of section 3.4 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.

3.12.2.2 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.

3.12.3 Construction Methods

3.12.3.1 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.

3.12.3.2 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 3.4-6, 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 metre 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.

3.12.3.3 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 3.9.3 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.

3.12.4 Measurement

Surface dressing work shall be measured under this item by the number of square metres of acceptable work completed.

3.12.5 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:

3/12/1 Primer Seal

Square Metre



3.13 BITUMINOUS SURFACE TREATMENT (plant method)

3.13.1 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.

3.13.2 Materials

3.13.2.1 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 3.4 of these Specifications. The bituminous material shall be approved by the Engineer.

3.13.2.2 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.

3.13.2.3 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 3.9-1 for the appropriate specified nominal size.

Table 3.13-1

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		
20	100	100	100
14	0 - 45	85 - 100	100
10	0 - 7	0 - 45	85 - 100
6.3	0 - 2	0 - 7	0 - 45
2.4	-	0 - 2	0 - 7
0.075	0 - 1	0 - 1.5	0 - 2

Notes on Table 3.10-1

- 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.

3.13.2.4 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.

3.13.2.5 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 portions 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.

3.13.3 Construction Methods

3.13.3.1 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 3.10.3.2
- 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 3.9.3.4(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 3.13.3.5.
- 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.

3.13.3.2 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.

3.13.3.3 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.

3.13.3.4 Application of Bituminous Material

The uniform application of bituminous material at the rate specified or ordered, reference is made to Table 3.9-2, 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 3.4-6. 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 3.13-2

Approximate Quantities of Materials for Surface Treatment per Square Meter		
Nominal Size of Aggregate (mm)	Rate of Application	
	Kilograms Aggregate	Litres 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 3.13-2

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 3.9-2, 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.

3.13.3.5 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.

3.13.3.6 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.

3.13.3.7 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.

3.13.4 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.

3.13.5 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 within 3/9/2. Pre-coating of chippings shall be carried out without any additional payment.

Pay items shall be:

3/13/1	Single Bituminous Surface Treatment	Square Metres
3/13/2(a)	Double Bituminous Surface Treatment- 20mm nominal size aggregate followed by 10mm (Machine Method)	Square Metres
3/13/2(b)	Double Bituminous Surface Treatment- 14mm nominal size aggregate followed by 10mm (Machine Method)	Square Metres

3.14 DENSE BITUMINOUS SURFACING (plant method)

3.14.1 Description

3.14.1.1 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 3.5, “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.

3.14.1.2 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 3.9.2.3 of these Specifications, if needed, coated with bitumen with the materials complying with Section 3.9.2 of these Specifications and with Table 3.10-1. 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 3.14-1 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 3.14-1.

Table 3.14-1

Mix Classification	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
25	75 – 90	100	100
20	65 – 85	85 – 97	100
14	55 -75	70 – 82	75 – 87
10	45 -65	61 – 73	63 – 75
5	30 -50	43 - 55	47 – 57
2.4	21 -38	29 – 38	33 – 42
1.2	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 – 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 shall be 4.0% and 4.5% for Dense Bituminous Surface Course and Dense Bituminous wearing Course respectively.

Our gradation table provides a larger scale of aggregate range. To find the more accurate well graded S-curve, some control points can be selected. The following two tables can also be used as mix type selection guide for long-life HMA pavements (Newcomb and Hansen, 2006).

Table 3.14-2

Pavement Layer	Mix Type	NMAS, mm	Lift Thickness	Traffic Level, MESAL _{2,3}

			Range, mm ¹			
				<0.3	0.3-10	> 10
Dense Bituminous Base Course	Dense, Fine	37.5	110-150	..	..	..
		25	75-100	..	..	..
		19	60-75	..	..	..
	Dense, Coarse	37.5	150-190	..	..	..
		25	100-125	..	..	..
		19	75-100	..	..	..
Dense Bituminous Surface Course	Dense, Fine	19	60-75	..	..	.
		12.5	40-60	..	..	.
		9.5	25-40	..	..	.
		4.75	15-20	..	..	.
	Dense, Coarse	19	75-100			..
		12.5	50-60			..
		9.5	40-50			..

- Notes: 1. Lift thickness conversion is approximate for practical design.
2. MESAL – Millions of Equivalent Sign Axle Loads
3. (.) Indicates “Recommended,” (..) Indicates “Strongly Recommended,”

To exert more control on the grading requirements to be well graded, relationship between nominal maximum aggregate size and primary control sieve shall be followed. If the mix maximum aggregate size has been selected, the percent of passing more than the corresponding value of the primary control sieve the mix will be fine-graded.

Table 3.14-3

Nominal Maximum Aggregate Size	Primary Control Sieve	Percent Passing
37.5 mm	9.5 mm	≥ 47
25.0 mm	4.75 mm	≥ 40
19.0 mm	4.75 mm	≥ 47
12.5 mm	2.36 mm	≥ 39
9.5 mm	2.36 mm	≥ 47

In addition to meeting the requirements of the job-mix formula and the allowable tolerances in Section 3.9, laboratory samples shall be prepared according to standard Marshall Methods in MS 2 of the Asphalt Institute USA 75 blows for per face. The sample shall be of approved material to the gradation and bitumen content stated and shall have the following characteristics.

1. Marshall Stability at 60⁰ 50 blows ≤ 1100kg for light traffic road

Marshall Stability at 60⁰ 75 blows ≤ 1300 kg for Medium and heavy traffic road

Marshall stability at 60⁰ 75 blows + Additional number of blows ≤ 2140 kg for very heavy

traffic road

Modified Marshall Method shall be used when required for heavyduty truck loading road.

2. Marshall Flow not less than 2 mm nor more than 4 mm.
3. Air voids in mix, base course, 3 – 5%’.
4. Air voids in Mix, wearing course, 3 - 5%
5. Voids filled with Bitumen, base course (VFA) 65 - 80%
6. Voids filled with Bitumen, wearing course (VFA) 70 - 80%
7. Voids in Mineral Aggregate (VMA)will be a function of the nominal maximum aggregate size as following table:

Mixture Nominal Maximum Aggregate Size, mm	Minimum Design VMA, volume %
37.5	11
25.0	12
19.0	13
12.5	14
9.5	15
4.75	16

8. Hamburg Wheel Tracking Device, 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 load cycles of 4 mm and 10 mm at 20000 load cycles, **or as decided by the Engineer at site**. To determine the Creep Compliance and Strength of Hot Mix Asphalt (HMA) using the Indirect Tensile Test Device as per AASHTO Designation T 322 – 07 (2016).

Table 3.14-4:

Bitumen Grade	Temperature Ambient	Resilient Modulus	Marshall Stability at 60°C	
20/30 PEN Grade	15°C	16,000-Mpa	3500kg	
35/50 PEN Grade	20°C	7000-Mpa		
40/50 PEN Grade	--	5000-Mpa		
60/70 PEN grade(unmodified)	25°C	3126 Mpa	1300 kg	

60/70 grade modified with SBS	20°C	12,429 Mpa	2400kg	
85/100 PEN Grade	25°C	1966 Mpa	1022.50 kg	
VG-30 grade	25°C	9,651 Mpa	2151.60kg	
85/100 pen grade	25°C	1966 Mpa	-	
PG 64-22 Grade	25°C	7,812 Mpa	3073.88 kg	Aged binder



Table 3.14-5: MARSHALL BLOW FOR ASPHALT MIX DESIGN

No of Marshall Blows		Traffic volume ESAL	
Compaction(number of blows each end of specimen)		Traffic LevelCategory	
Marshall blows	75	Medium traffic	From 10^4 and 10^6
Marshall blows	75	Heavy traffic	above $\geq 10^6$

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.

3.14.2 Materials

3.14.2.1 General

The materials shall conform to Section 3.9.2 of these Specifications with the additional requirements noted below.

3.14.2.2 Bituminous Materials

These materials shall conform to the requirements of Section 3.4. The bituminous material shall be of 60/70 penetration grade.

3.14.2.3 Bitumen Additive

An adhesion and anti-stripping agent shall be added to the bituminous material where so specified or when the Engineer's 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.

3.14.2.4 Coarse Mineral Aggregates

The provisions of Section 3.9.2.1 shall apply.

3.14.2.5 Fine Mineral Aggregate

The provisions of Section 3.9.2.2 shall apply.

3.14.2.6 Mineral Filler

The provisions of Section 3.9.2.3 shall apply.

3.14.2.7 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 Specimens to be prepared (STP 10.9) 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.

3.14.3 Construction Methods

3.14.3.1 General

Construction methods shall conform to the requirements of Section 3.9.3 of these Specifications subject to the following modifications.

3.14.3.2 Preparation of Bituminous Material

Bitumen shall be heated to a temperature between 121°C and 163°C. The Contractor shall submit a single definite temperature for the Engineer's approval.

3.14.3.3 Preparation of Mineral Aggregate

The mineral aggregates shall be dried and heated to a temperature between 135°C and 177°C 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.

3.14.3.4 Preparation of Mixture

The mixture shall when emptied from the mixer be at a temperature within the absolute limits of 135°C and 165°C. A single definite temperature shall be submitted for the Engineer's approval in accordance with Section 3.9.1.3.

3.14.3.5 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 3.11, 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 temperature of 107°C. Smoothing rolling may continue longer, if necessary, as long as the temperature of the mat is above 90°C. The average field density of any bed of base course and wearing courses shall be between 93 – 98 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 97% of the laboratory density of the Marshall density.

3.14.3.6 (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

- LJCT 1 (3:1 Taper Rolled from Hot Side)

The unconfined edge of the first paved lane was constructed with a 3:1 taper at the proposed joint. Normally, a steel plate is rigidly attached to the screed to give the desired taper. However, on this project a piece of steel plate was dragged by chain behind the screed. The resulting taper was not as smooth as would be obtained with a plate rigidly attached to the screed. The taper was then tacked with bitumen, and a conventional overlapping technique was used to place the hot side material on the following day. The end gate of the paver extended about 25 to 38 mm (1 to 1.5 inch) over the top surface of

the previously placed material. The height of the uncompacted material above the previously placed material was about 6 mm (1/4 in.) for each 25 mm (1 inch) of compacted material placed. Noluting was done. The joint was compacted from the hot side, overlapping the cold side of the joint approximately 152 mm (6 in.). This type of compaction, in which the major portion of the roller weight travels on the hot side, is believed to result into a good bond between the cold and hot sides of the joint.

- LJCT 2 (3: 1 Taper Rolled from Cold Side)

The only difference between this method and LJCT 1 is that the rolling was done with a major portion of the roller wheel on the cold side with about 152 mm (6 in.) of the roller wheel on the hot side of the joint. This technique is believed to produce a “pinching” effect on the joint.

However, timing in this type of rolling is critical. When the roller is operated on the cold side, the hot side undergoes cooling which can make it difficult to achieve the desired compaction level.

- LJCT 3 (3: 1 Taper Rolled from Hot Side 152 mm Away)

Compaction in this method was started with the edge of the roller about 152 mm (6 in.) from the joint on the hot side. Other than that, this method is similar to LJCT 1. The lateral pushing of the material toward the joint during the first pass of the roller is believed to produce a high density at the joint. This method is particularly recommended by some asphalt paving technologists for tender mix or thick lifts, which have the potential for the mix to be pushed towards the joint.

- LJCT 4 (Taper Removed and Tack Coated)

In this method, the cold side unconfined edge was constructed with a 3:1 taper. Then the full width of the taper was removed on the following day with a cutting wheel attached to a motor grader. Since the material had cooled, the cutting was done very carefully, avoiding any disturbance to the lower lifts. The hot side material was then placed after applying a tack coat on the vertical face of the cut. Lay down and compaction were achieved as indicated in LJCT 1, that is, rolling of the joint is accomplished from the hot side. Initially, cutting could not be done in a straight line because the operator of the motor grader did not have experience in this operation. Later, a straight line cut is obtained.

- LJCT 5 (Taper Removed but no Tack Coat)

This type of joint was constructed in the same way as LJCT 4 except that no tack coat was applied to the vertical face before placement of the adjacent hot lane.

- LJCT 6 (3:1 Taper with 25 mm Offset)

In this method, the cold side unconfined edge was constructed with a 25.4 mm (1 in.) vertical step (offset) at the top of the joint. The remainder of the joint was constructed with a 3:1 taper (Figure 2). The vertical face was not tacked, but the taper surface was tacked, before placement of adjacent hot material and subsequent rolling according to the method of LJCT 1 (rolling from hot side). The vertical step (offset) is formed by placing a 610 mm (2 feet) long piece of 51mm x 51 mm (2 in. x 2 in.) angle iron under the drag device used to form the 3:1 taper.

- LJCT 7 Asphalt Tack Coat)

The unconfined edge of the first paved lane adjacent to the joint is not provided with any taper in this experimental section. On the following day, a rubberized asphalt tack coat is applied on the face of the unconfined edge before placing the adjacent lane. The thickness of the tack coat is about 3 mm (1/8 in.). Lay down and compaction of the adjacent lane were achieved following the procedures in LJCT

1 (rolling from hot side). As mentioned earlier, no luting was done on this entire project. The cores are taken on the joint that the hot lane overlap is about 3 mm to 5 mm (1/8 in. to 3/16 in.) higher than the cold mat after compaction in most test sections.

3.14.3.7 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 6 hours after completion of the pavement, except with the approval of the Engineer.

3.14.3.8 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, as 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.

3.14.3.9 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.

3.14.4 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.

3.14.5 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:

3/14/1	Dense Bituminous Surfacing - Base Course (Pen grade bitumen)	Cubic Metre
3/14/2	Dense Bituminous Surfacing - Base Course (Modified bitumen)	Cubic Metre
3/14/3	Dense Bituminous Surfacing -Wearing Course (Pen grade bitumen)	Cubic Metre
3/14/4	Dense Bituminous Surfacing - Wearing Course (Modified bitumen)	Cubic Metre

3.15 BITUMINOUS CARPETTING (PLANT METHOD) [APPLICABLE FOR MAINTENANCE AND EMERGENCY PURPOSES AND NEEDS SPECIAL PERMISSION FROM PROPER AUTHORITY]

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.

The provisions of Section 3.9, “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 3.9.2 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 3.11-1.

The selected job-mixes shall conform to Table 3.15-1, unless with the specific approval of the Engineer.

Table 3.15-1

Mix classification	1	2
Course	Base (Binder)	Base (Binder)
Thickness (mm)	25	38 or 50
Sieve Size (mm)	Total % by weight passing	
25	100	100
20	100	75-100
12.5	75-100	60-80
10	60-80	-
5.0	40-60	40-60
2.4	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 3.9.2 of these Specifications with the additional requirements noted below.

3.15.2.2 Bituminous Materials

These materials shall conform to the requirements of Section 3.4. The bituminous material shall be 60/70 penetration grade.

3.15.2.3 Coarse Mineral Aggregate

The provision of Section 3.9.2.1 shall apply.

3.15.2.4 Fine Mineral Aggregate and Mineral Filler

The provision of Sections 3.9.2.2 and 3.9.2.3 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 3.14.3 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 binder course of 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, garden dimensions and cross sections shown on the Drawings or as required by the Engineer.

The provisions of Section 3.5, "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.

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 3.5.2 of these specifications. The Contractor shall meet the requirements of the job mix formula in section 3.5.1.3 and the tolerances in Section 3.5.1.4

The material shall conform to Table 3.12-1 below, unless otherwise directed by the Engineer in writing.

Table 3.16-1

Mix Classification Course Compacted Thickness (mm)	Seal Coat 7 mm	Seal Coat 12 or 15 mm
Sieve Size (mm)	Total % by weight passing	
10	-	100
6.3	100	90-100
5	90-100	75-95
2.4	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 3.5.2 of these specifications with the additional requirements noted below.

3.16.2.2 Bituminous Materials

These materials shall conform to the requirements of Section 3.4. 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 down graded 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 sand. Sand shall be dry 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 following grading given Table 3.12-1

3.16.2.4 Mixture

The Contractor shall carry out regular checks at frequency to be determined by the Engineer of 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 3.5.3 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 3.5.3 shall be replaced by those under Sections 3.12.3.2, 3.12.3.3 and 3.12.3.4 of these Specifications.

Following approval of the mix formula the contractor shall undertake short trial sections of approximately 10 metres 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 been 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 3.12.3.2 through 3.12.3.5.

3.16.3.2 Preparation of Bituminous Material

Bitumen shall be heated in a tar boiler to a temperature between 121°C and 163°C. 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 150°C 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 °C. When the temperature is falling and reaches 155°C the fire box should be refilled with wood and re-ignited as the temperature will soon fall below 150°C. The operation is repeated as the temperature again regains 150°C. 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 163°C 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 (163°C).

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 mixture, 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 6 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 3.11 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 ;

3/12/1 7mm Compacted Premix Bituminous Seal Coat Square Metre 3/12/2 12mm Compacted Premix Bituminous Seal Coat Square Metre 3/12/3 15mm Compacted Premix Bituminous Seal Coat Square Metre

3.17 THIN HMA OVERLAYS FOR PAVEMENT PRESERVATION AND LOW VOLUME ASPHALT ROAD with 4.75 NMAS (thickness 19mm to 25mm) [APPLICABLE for maintenance and emergency purposes AND NEEDS special permission from proper AUTHORITY]

3.17.1 Composition of the Mixture:

AASHTO (specification M 323) specification requirements for 4.75 mm mixtures are summarized in Table 3.16-1

- An FAA of at least 45 is recommended for over 0.3 million ESALs. Alternatively, the percentage natural sand should be limited to 15 percent maximum.
- The gradation requirements should be changed to 30-55% passing the 1.18 sieve and 6-13% passing the 0.075 mm sieve.

Table 3.17-1

Seive size	Min %passing	MIX-PARAMETERS	
12.5 mm	100	Marshall blow	50
9.5 mm	95	FAA(Fine aggregate angularity	45
4.75mm	90	SE(Sand Equivalent)	40
1.18 mm	30	VMA	16
0.075mm	6	VFA	70-80
0.075	12	AIR VOID(Va)	4,0%

		DENSITY(initial)	≤92.15
		Expected extended life of pavement	13 years
		60/70 grade PEN Binder	5.5-6.5%
		ESAL	≤ 3-10 Million

3.17.1.1 Leveling and Patching

Two possible uses for 4.75 mm NMAH mixtures are a leveling course or patching mix. A leveling course is defined as, a course (asphalt aggregate mixture) of variable thickness used to eliminate irregularities in the contour of an existing surface prior to superimposed treatment or construction. A smaller aggregate size mixture is beneficial for leveling applications where very thin lifts are needed to correct surface defects.

Patches are needed to repair weak areas in pavements, pot holes, or utility cuts. Structural patches should be designed and constructed with full depth asphalt concrete to ensure strength equal to or exceeding that of the surrounding pavement structure. Generally, there are three types of asphalt patching mixtures used: (a) hot mixed, hot laid, (b) hot mixed, cold laid, or (c) cold mixed, cold laid. Dense graded aggregates are used primarily for hot mixed, hot laid patching mixtures

Typical gradations of dense graded patching mixtures are presented in Table 3-16-2 which shows that the current AASHTO gradation limits for 4.75 mm NMAH mixtures would fall within the limits of gradation C. The majority of all patching mixtures have 9.5 mm or 12.5 mm NMAH gradations (9). However, some agencies do specify a 4.75 mm NMAH mixture for patching. Larger NMAH mixtures seem to be preferred because they provide better stability, especially in deeper patches. When shallow holes are filled, a smaller NMAH mixture is beneficial, especially when the mixture must be feathered at the edges.

Table:3.17-2 Typical Gradations of Dense-Graded Patching Mixtures

Sieve size	Percent passing A	Percent passing B	Percent passing C
19 mm	100		
12.5 mm	90-100	100	
9.5 mm	75-90	90-100	100
4.75 mm	47-68	60-80	80-100
2.36 mm	35-52	35-65	65-100
1.18 mm	24-40	-	40-80
0.600 mm	14-30	-	20-65

0.300 mm	9-20	6-25	7-40
o.075	2-9	2-10	2-10

3.17.1.2 Thin Overlays and Surface Mixtures

It may be ideal to use 4.75 mm NMAS mixtures for thin overlays and surface mixtures. Hansen, stated that HMA overlays are probably the most versatile pavement prevention techniques available. They can improve structural capacity, improve ride, enhance skid resistance, reduce noise and improve drainage. However, thin overlays should only be placed on structurally sound pavements that exhibit surface distresses such as low-severity transverse and longitudinal cracking. According to NCHRP Report 531, lift thickness should be at least three to four times the NMAS. For a thin overlay (less than one inch), a 4.75 mm NMAS asphalt mixture would meet a lift thickness to NMAS ratio of three to four. The main function of a thin overlay of HMA may not be to provide strength to the pavement structure, but to protect a deteriorating pavement. If a thin overlay of 4.75 mm NMAS dense graded HMA is used as a surface mixture, it may provide a smooth, durable, water-tight surface. However, one possible concern of applying this type of mixture as surface mix is producing low surface texture. A low macro texture might lead to poor skid resistance, especially when a surface is wet.

3.17.2.1 Preparation of Thin Overlay Mixture

The mineral aggregates shall be dried and heated to a temperature between 135°C and 177°C 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.

3.17.2.2 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.

3.17.2.3 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 6 hours after completion of the pavement, except with the approval of the Engineer.

3.17.2.4 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, as 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.

3.17.2.5 Surfacing Texture

The surface finish of the thin overlay shall be 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.

3.17.3 Measurement

The quantities of thin dense bituminous overlay 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.

3.17.4 Payment

The quantities of thin dense bituminous overlay 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:

3/17/1	Dense Bituminous Patching----Levelling Course	Cubic Metre
3/17/2	Thin Dense Bituminous overlay – Thin overlay Course	Cubic Metre

3.18 RECYCLING OF BITUMINOUS PAVEMENTS (RECLAIMED ASPHALT PAVEMENT)

3.18.1 Scope

This work covers the recycling of existing bituminous pavement materials to upgrade an existing bituminous pavement which has served its initially intended purpose. Materials to be removed or to be reprocessed from the bituminous layers in pavement can be termed as Reclaimed Asphalt Pavement (RAP). To introduce environment friendly and cost effective approaches RAP shall be used as an Asphalt Treated Base (ATB) conforming the criteria mentioned below. The work shall be performed on such widths and lengths as shall 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. These specifications cover the hot process.

If criteria of RAP to use in ATB cannot be confirmed rather the quality is lower which effectively fulfill the requirements of Sub-base material, it can be used as sub base material. Whereas the RAP containing moss or can be categorized as unsuitable materials can be discarded as decided and appropriated by the Engineer.

3.18.2 Construction of Asphalt Treated Base (ATB) using RAP

During the process of pavement reconstruction or rehabilitation, it's crucial to assess the condition of the existing pavement as it often serves as a solid foundation for the new pavement. In cases where the existing pavement is significantly deteriorated, or when constraints such as urban road level restrictions or scarcity of road materials are present, a more innovative approach involves dismantling the existing pavement and using the

RAP in pavement reconstruction. The dismantled materials i.e. RAP, including aged asphalt concrete can be pulverized and processed as an Asphalt Treated Base course to reduce the layer depth of new asphalt layers.

This work shall consist of removing existing bituminous layers by milling machine or other method as prescribed by Engineer to a depth up to 150 mm, or as ordered by the Engineer, and over a width as indicated on the Drawings or as instructed by the Engineer. The material shall be thoroughly mixed by means of a motor grader and homogenised with a pulvimixer or similar approved plant.

To effectively construct ATB layer, it is essential to engage experienced Materials Engineers and Technicians equipped with the necessary knowledge and resources. The process of preparing mix designs incorporating RAP, virgin aggregates, and fresh bitumen demands meticulous attention and specialized testing. The percentages of RAPs to be used will be defined by the aggregate properties of RAP to be confirmed as per that of Dense Bituminous Base Course. Generally in case of Bangladesh 15% to 20% of RAP can be used depending upon the aggregate properties, scope and value of works stipulated in contract, or as approved by the Engineer upon proper testing.

Trial mixes and field trials should be conducted to assess the performance of RAP blended with fresh aggregates and fresh bitumen. The process can be utilized with or without rejuvenator as per the instruction of the Engineer or as assessed by the mix design trial.

Dense Bituminous Base Course Up to 50mm can be constructed using RAP as ATB with mix design as instructed or appropriated by the Engineer. For national and regional highways, a properly designed wearing Base course and wearing surface course should be employed on ATB to ensure long-term durability and performance.

When conducting mix designs, it is imperative to follow established procedures such as the Marshall Method. This involves thorough testing of RAP bitumen properties, either through extraction from existing asphalt or by trial and error methods if extraction facilities are unavailable.

Additionally, specific gravity tests should be carried out, adhering to standard protocols. During production in batching plants, strict control measures should be implemented to maintain temperature levels below 160 degrees Celsius in the drier, and RAP materials must be adequately air-dried before processing.

In summary, the utilization of RAP offers a sustainable solution for asphalt mixtures, provided that thorough planning, testing, and quality control measures are implemented throughout the process. By adhering to best practices and leveraging the expertise of qualified professionals, the benefits of RAP can be realized while ensuring the integrity and performance of road infrastructure.

Reclaimed Asphalt Pavement (RAP) shall be used in the national highways with permission from proper authority as sub-base or ATB.

3.18.3 Method Statement for Asphalt Treated Base (ATB) Construction

This method statement outlines the general procedures for constructing Asphalt Treated Base (ATB) using recycled materials from existing aged asphalt concrete, aggregate base, and sub base. Specific project requirements and local regulations should be considered during implementation.

a. Preparation of Existing Pavement:

- Use scarifying and crushing equipment to process the existing pavement.
- Stockpile the crushed mix in designated areas, preventing segregation.

b. Aggregate Testing

- Collect aggregate samples from stockpiles. Ensure proper separation of aggregates for accurate testing.
- Conduct standard tests to determine aggregate properties such as absorption and specific gravity.

c. ATB Specifications:

- Adhere to ATB specifications (grading and other requirements to be satisfied as the specifications of Dense Bituminous Base Course), as instructed by the Engineer, allowing for a variety of gradations and aggregate qualities.
- Avoid pavement layers thinner than two to three times the nominal aggregate size to prevent compaction difficulties, tearing under the paver screed, and potential crushing of large particles during compaction.
- Maintain a maximum aggregate size of 50mm, with passing 75 microns limited to a maximum of 10%.

d. Mix Design:

- Perform mix design in accordance with the Marshall Method.

e. Batching Plant Operations:

- Maintain a recommended maximum temperature of 160°C in the drier of the batching plant.
- Follow standard procedures for mixing in the plant and paving on the roadway. Monitor mix quality throughout the production process.

f. Site Preparation

- Clear the work area of any obstructions.
- Ensure safety measures are in place, including proper signage and barricades.

g. Paving

- Transport the prepared ATB mix to the designated paving area.
- Use appropriate paving equipment to lay the ATB mix evenly.
- Compact the ATB using rollers to achieve the required density. Density of core samples taken from the paved area shall be compared with Maximum Theoretical Density Gmm measured at site laboratory on asphalt mix.
- Ensure proper joint construction and surface finishing.

h. Quality Control

- Conduct regular quality control checks during construction to ensure compliance with specifications.
- Address any deviations promptly to maintain the integrity of the ATB structure.

i. Completion and Cleanup

- Complete the ATB construction as per project specifications.
- Remove any excess materials and equipment from the site.
- Conduct a final inspection to ensure the work meets quality standards and safety requirements.

j. Payment

The quantities of Asphalt Treated base course measured as provided above shall be paid for at the Contract unit rates. The rates and payments shall be full compensation for stockpiling, excavating, furnishing and placing all materials including all labor, equipment, tools, trials, preparation of job mix formulae, testing, making test holes and all incidentals necessary to complete the work. Tack coat shall be paid separately.

Pay items shall be:

3/18/1 Preparation and construction of ATB.....	Cubic metre
1. Excavating and rotovating the existing pavement down to bottom of base type 1.....	Cubic metre
2. Stockpiling and pulverising the scarified material.....	Cubic metre
3. Compacting the foundation (95% of MDD)	Square metre
4. Asphalt Treated Base course.....	Cubic metre

3.19 BRICK PAVEMENT

3.19.1 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.

3.19.2 Subgrade and Improved Subgrade

The subgrade or improved subgrade shall conform to the provisions of Sections 3.23.1.

3.19.3 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.

3.19.4 Brick on End Edging

3.19.4.1 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.

3.19.4.2 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.

3.19.5 Single Layer Brick Flat Soling

3.19.5.1 Description.

This item consists of providing single layer brick flat soling on accepted subgrade or improved subgrade.

3.19.5.2 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.

3.19.6 Brick on Edge Pavement in Herringbone Bond

3.19.6.1 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.

3.19.6.2 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.

3.19.6.3 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.

3.19.7 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.

3.19.8 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:

3/19/1	Brick on End Edging	Linear Metre
3/19/2	Single Layer Brick Flat Soling including 75 mm thick Compacted Sand Cushion	Square Metre
3/19/3	Herring Bond Brick Pavement including 12 mm Sand Cushion	Square Metre

3.20 DRY LEAN CEMENT CONCRETE

3.20.1 Scope

3.20.1.1

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.

3.20.1.2

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.

3.20.2 Materials

3.20.2.1 Cement:

Cement shall confirm to the requirements of Section-5.1.2 of General Specifications.

3.19.2.2 Aggregates:

Aggregates shall confirm to the requirements of Section-5.1.2 of General Specifications.

3.20.2.3 Water:

Water shall confirm to the requirements of Section-5.1.2 of General Specifications.

3.20.3 Proportioning of Materials for the Mix

3.19.3.1

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.

3.20.3.2 Moisture content:

Moisture content shall confirm to the requirements of Section-5.1.2.3 of General Specifications.

3.20.3.3 Cement content:

Cement content shall confirm to the requirements of Section-5.1.2.3 of General Specifications.

3.20.3.4 Concrete strength:

Concrete strength shall confirm to the requirements of Section-5.1.2.3 of General Specifications.

3.20.4 Construction

3.20.4.1 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.

3.20.4.2 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 3.15.9.3.2. 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.

3.20.4.3 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 3.14.5.5.2 will be adhered to.

3.20.4.4 Placing:

Lean concrete shall be laid/placed by a paver with electronic sensor. 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.

3.20.4.5 Compaction

3.20.4.5.1

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.

3.20.4.5.2

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.

3.20.4.5.3

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 compactibility 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.

3.20.4.5.4

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.

3.20.5 Trial Mixes

Trial Mixes shall confirm to the requirements of Section-5.1.2.3 of General Specifications.

3.20.6 Curing

Curing shall confirm to the requirements of Section-5.1.3.11 of General Specifications.

3.20.7 Removal of Scaffolding and Formwork

Forms and scaffolding shall confirm to the requirements of Section-5.1.3.12 of General Specifications.

3.20.8 Repair of Concrete

Repair of Concrete shall confirm to the requirements of Section-5.1.3.12 of General Specifications.

3.20.9 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.

3.20.10 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.

3.20.11 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.

3.20.12 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 items shall be:

03/20/01	Dry Lean Concrete (as specified in Design)	cu. Metre

3.21 CEMENT CONCRETE PAVEMENT

3.21.1 Scope

3.21.1.1 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 labour and performing all operations in connection with the work, as approved by the Engineer.

3.21.1.2

The design parameters, viz., thickness of pavement slab, grade of concrete, joint details etc. shall be as stipulated in the contract drawings. Concrete pavement can be jointed, jointed reinforced and continuously reinforced concrete. Reinforcement often for crack control. Rollar compacted concrete and pervious or porous concrete is commonplace.

Thicker pavements can carry more loads, because flexural stresses are reduced and fatigue life of the pavement is increased.

Jointed plain concrete pavement (JPCP), consists of unreinforced concrete slabs 3.6 to 6.0 m in length with transverse contraction joints between the slabs so the pavement expansions and contractions are addressed through joints. Dowels should be provided across the joint for load transfer. Dowels are smooth rods, generally plain or epoxy-coated steel, which are usually greased or oiled on side to allow the joints to open and close without resistance. JPC pavements, like other conventional concrete pavements, often use tie bars to connect adjacent traffic lanes. Tie bars are deformed reinforcing steel and, unlike dowels, are not intended to allow the joints to open and close. JPCP is the most commonly used type of concrete pavement because it is usually the cheapest to construct.

Jointed reinforced concrete pavement (JRCP) has typically steel content of 0.01 to 0.25 percent of the cross-sectional area, in the longitudinal direction, with less steel in the transverse direction. Either individual reinforcement bars or wire fabric and meshes may be used. Because the steel is placed at the neutral axis or midpoint of the slab, it has no effect on the flexural performance of the concrete and serves only to keep cracks together.

Continuously reinforced concrete pavement (CRCP) is characterized by heavy steel reinforcement and absence of joints. Typically steel content is 0.4 to 0.8 percent by volume in the longitudinal direction. Steel in the transverse direction is provided in a lower percentage as temperature steel. Cracks form in CRCP approximately 0.6 to 2 m apart. The reinforcement holds the cracks tightly together and provides for aggregate interlock and shear transfer. CRCP pavement provides a smoother ride and a longer life than any other type of pavement.

3.21.2 Materials

3.21.2.1 Cement:

Cement shall conform to the requirements of Section-5.1.2 of General Specifications.

3.21.2.2 Admixtures:

Admixtures shall conform to the requirements of Section-5.1.2 of General Specifications.

3.21.2.3 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).

3.21.2.4 Water:

Water shall confirm to the requirements of Section-5.1.2 of General Specifications.

3.21.2.5 Admixtures:

Admixtures shall confirm to the requirements of Section-5.1.2 of General Specifications.

3.21.2.6 High Yield Deformed Steel Reinforcing Bars for dowels and tie bars:

Reinforcing bars for dowels and tie bars shall confirm to the requirements of Section-5.2 of General Specifications.

3.21.2.7 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.

3.21.2.8 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).

3.21.2.9 Storage of materials:

Storage of materials shall confirm to the requirements of Section-5.1.3.3 of General Specifications.

3.21.3 Proportioning of Concrete

3.21.3.1

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.

3.21.3.2 Cement content:

Cement content shall confirm to the requirements of Section-5.1.2.3 of General Specifications.

3.21.3.3 Concrete strength:

Concrete strength shall confirm to the requirements of Section-5.1.2.3 of General Specifications.

3.21.3.4 Workability

3.21.3.4.1

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. Usually no slump concrete should be used for pavement works.

3.21.3.4.2

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.

3.21.3.5 Design mix

3.21.3.5.1

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.

3.21.3.5.2

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.

3.21.3.5.3

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 order of the Engineer.

3.21.4 Separation Membrane

A separation membrane shall be used between the concrete slab and the 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.

3.21.5 Joints

3.21.5.1

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.

3.21.5.2 Transverse joints

3.21.5.2.1

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 3.15.11.

3.21.5.2.2 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 $\pm$ 5 mm or as stipulated in the drawings and dowel bars complying with Clause 3.15.6.5 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.

3.21.5.2.3 Expansion joints:

The expansion joints shall consist of a joint filler board complying with Clause 3.15.2.7 and dowel bars complying with Clause 3.15.6.5 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 3.15.6.2.1 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.

3.21.5.3 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.

3.21.5.4 Longitudinal joint

3.21.5.4.1

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 $\pm$ 5 mm as indicated in the drawing.

3.21.5.4.2

Tie bars shall be provided at the longitudinal joints as per dimensions and spacing shown in the drawing and in accordance with Clause 3.15.6.6.

3.21.6 Dowel bars

3.21.6.1

Dowel bars shall be mild steel rounds in accordance with Clause 3.15.2.6 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.

3.21.6.2

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 centre line of the carriageway and to each other within tolerances given hereunder, the compliance of which shall be checked as per Clause 3.16.10.7.

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

For all bars inserted after laying of the slab:

Twice the tolerance for alignment as indicated in (i) above

3.21.6.3

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.

3.21.6.4

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 fail 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.

3.21.6.5

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.

3.20.6.6

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.

3.21.6.7 Tie bars

3.21.6.7.1

Tie bars in longitudinal joints shall be deformed steel bars of strength in accordance with Clause 3.15.2.6. The bars shall be free from oil, dirt, loose rust and scale.

3.21.6.7.2

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.

3.21.6.7.3

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.

3.21.6.7.4

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.

3.21.7 Weather and Seasonal Limitations

3.21.7.1 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.

3.21.7.2 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.

3.21.8 Side Forms, Rails

3.21.8.1 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 regularity 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.

3.21.8.2

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.

3.21.9 Construction

3.21.9.1 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 lime-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 atleast 300 m in one day.

3.21.9.2 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.

3.21.9.3 Equipment for proportioning of materials and paving

3.21.9.3.1

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.

3.21.9.3.2 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.

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.

3.21.9.3.3 Paving equipment:

The concrete shall be placed with an approved fixed form or slip from 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.

3.21.9.4 Hauling and placing of concrete

3.21.9.4.1

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 days work.

3.21.9.4.2 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.

3.21.9.4.3

Where fixed form pavers are to be used, forms shall be fixed in advance as per Clause 3.15.8. 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.

3.21.9.4.4

In all cases, the temperature of the concrete shall be measured at the point of discharge from the delivery vehicle.

3.21.9.4.5

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.

3.21.9.4.6

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.

3.21.9.4.7

While the concrete is still plastic, its surface shall be brush textured in compliance with Clause 3.16.9.8 and the surface and edges of the slab cured by the application of a sprayed liquid curing membrane in compliance with Clause 3.15.9.9. 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.

3.21.9.4.8

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.

3.21.9.4.9

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.

3.21.9.5 Construction by fixed form paver

3.21.9.5.1

The fixed form paving train shall consist of separate powered machines which spread, compact and finish the concrete in a continuous operation.

3.21.9.5.2

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.

3.21.9.6 Construction by slip form paver

3.21.9.6.1

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 crossfall.

3.21.9.6.2

The level of the conforming plate and finishing beams shall be controlled automatically from the guide wires installed as per Clause 3.16.8 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.

3.21.9.6.3

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.

3.21.9.6.4

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 3.16.14, 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.

3.21.9.7 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.

3.21.9.8 Surface texture

3.21.9.8.1

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.

3.21.9.8.2

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.

3.21.9.8.3

The texture depth shall be determined by the Sand Patch Test as described in Clause 602.12. 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.

3.21.9.8.4

Texture depths shall not be less than the minimum required when measurements are taken as given in Table 600-2 nor greater than a maximum average of 1.25 mm.

TABLE 3.21-1

Time of Test	Number of Measurements	Required Texture Depth (mm)	
		Specified Value	Tolerance
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
Not later than 6 weeks before the road is opened to public traffic.	An average of 5 measurements	1.00	+ 0.25-0.35

3.21.9.8.5

After the application of the brushed texture, the surface of the slab shall have a uniform appearance.

3.21.9.8.6

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.

3.21.10 Preparation and Sealing of Joint Grooves

3.21.10.1 General

All transverse joints in surface slabs shall be sealed using sealants described in Clause 3.15.2.8. Joints shall not be sealed before 14 days after construction.

3.21.10.2Preparation of joint grooves for sealing

3.21.10.2.1

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.

3.21.10.2.2

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

3.21.10.2.3

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.

3.21.10.2.4

The groove shall be cleaned and dried at the time of priming and sealing.

3.21.10.2.5

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.

3.21.10.3Sealing with sealants

3.21.10.3.1

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.

3.21.10.3.2

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.

3.21.10.3.3

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.

3.20.10.3.4

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.

3.21.10.3.5

Sealant shall be applied, slightly to a lower level than the slab with a tolerance of 5 ± 2 mm.

3.21.10.3.6

During sealing operation, it shall be seen that no air bubbles are introduced in the sealant either by vapours or by the sealing process.

3.21.10.3.7 Curing:

Curing shall confirm to the requirements of Section-5.1.3.11 of General Specifications. Concrete temperature should be controlled as delayed ettringite formation (DEF), is a form of internal sulfate attack that can happen with steam-cured and mass concrete when internal concrete temperatures exceed 70°C .

3.21.11 Removal of Scaffolding and Formwork:

Forms and scaffolding shall confirm to the requirements of Section-5.1.3.12 of General Specifications.

3.21.12 Repair of Concrete:

Repair of Concrete shall confirm to the requirements of Section-5.1.3.12 of General Specifications.

3.21.13 Measurement of Texture Depth- Sand Patch Method

3.21.13.1 The following apparatus shall be used:

- A cylindrical container of 25 ml internal capacity
- 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
- Dry natural sand with a rounded panicle shape passing a 300 micron IS sieve and retained on a 150 micron IS sieve.

3.21.13.2 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.

3.21.13.3

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.

3.21.14 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.

3.21.15 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.

3.21.16 Method Statement for concrete pavement construction

3.21.16.1 Introduction:

This method statement outlines the procedure for the construction of concrete pavement. It covers the steps involved in the preparation, placement, and finishing of concrete to achieve a durable and ordinary-quality pavement.

3.21.16.2 Scope

This method statement applies to the construction of concrete pavements.

3.21.16.3 Equipment and Materials

The following equipment and materials will be required for the construction of concrete pavement:

- Compaction equipment (e.g., rollers, plate compactors)

- Concrete batching plant
- Concrete mixers
- Concrete vibrators
- Steel reinforcement bars (if required)
- Formwork materials
- Concrete testing equipment
- Finishing tools (e.g., screeds, trowels)
- Water source



3.21.16.4 Procedure:

Site Preparation:

- Clear the construction area from any debris, vegetation, or obstructions.
- Excavate and prepare the subgrade as per the project specifications, ensuring proper compaction and grading.
- Install any necessary subbase or base layers, if specified.

Formwork:

- Set up formwork along the edges of the pavement, ensuring proper alignment and adequate support.
- Apply form release agent to the formwork to facilitate easy removal after concrete placement.

Concrete Mixing and Delivery:

- Set up the concrete batching plant at an appropriate location.
- Ensure that the concrete mix design meets the project specifications, including the required strength, slump, and any additional admixtures.
- Regularly check and calibrate the batching plant to maintain accurate proportions of materials.
- Deliver the concrete to the construction site using concrete mixers, ensuring a continuous supply.

Concrete Placement:

- Pour the concrete into the prepared formwork, taking care to avoid segregation and honeycombing.
- Use concrete vibrators to consolidate the concrete and remove any air voids.
- Monitor the concrete placement process to maintain a consistent thickness and level.

Finishing:

- Use screeds or laser levelling devices to achieve the desired pavement elevation and slope.
- Strike off excess concrete using a straightedge or screed, ensuring a uniform surface.
- Finish the surface with trowels to achieve the desired texture and smoothness.
- Cure the concrete using appropriate curing methods such as curing compounds, moist curing, or curing blankets.

Joints and Edges:

- Install contraction joints at predetermined intervals to control cracking and allow for the expansion and contraction of the concrete.
- Finish the joint edges using appropriate jointing tools or devices.
- Install edge restraints, if required, to prevent the displacement of the pavement.

Quality Control and Testing:

- Regularly sample and test the concrete during construction to ensure it meets the specified requirements.
- Conduct slump tests, compressive strength tests, and any other required tests as per the project specifications.
- Monitor the curing process and take necessary measures to maintain adequate moisture levels.

3.21.16.5 Health, Safety, and Environmental Considerations:

- Provide adequate personal protective equipment (PPE) to all workers.
- Ensure proper ventilation and dust control measures during concrete mixing and placement.

Follow local regulations and best practices for the disposal of waste materials and excess concrete.

3.21.17.6 SAMI (Stress Arresting Membrane Interlayer) on Concrete Bridge Decks

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.

3.21.17.6.1 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.

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.

3.21.17 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 lie rod.

3.21.17.1 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.

3.21.18 Rate

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:

03/21/01	Cement Concrete Pavement (Concrete class-30)	cu metre
03/21/02	Cement Concrete Pavement (Concrete Class - 35)	cu metre
03/21/03	SAMI for Bridge Decks	Square Meter

SECTION 7

GENERAL SPECIFICATIONS

DIVISION 4- FOUNDATIONS

DIVISION 4

FOUNDATION WORK



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 bridges, including the provision of all materials and structures in accordance with these Specifications and in conformity with the requirements of the Drawings or other parts of the Contract Documents.

Piles through water and soft upper 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 bored to the pile toe or to a level approved by the Engineer. The temporary casing shall be withdrawn.

Under certain circumstances the Contractor may be permitted to bore all or part of the pile without casing under water or use drilling fluid to stabilize the borehole as referred to in Section 4.1.2.4.

The piles shall be concreted and reinforced to resist pile loads and horizontal forces on the pile caps according to the Drawings and these Specifications.

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 AASHTO Standard Specification M 183-79 (ASTM A36) or equivalent.

The minimum thickness of the permanent steel casing shall be 10 mm. However, the thickness may be waived to 6(six) mm, if specified in Drawings. 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 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 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.

4.1.2.2 Concrete

The concrete shall conform to Section 5.1 of these Specifications. 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

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.

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 inside casings shall at all times be at least 2 metres higher than outside the casings.

3. Carefully clean up all mud or sedimentation from the bottom of borehole.
4. Place reinforcement cage, inspection pipes etc.
5. Concrete continuously under water, or drilling fluid, by use of the tremie method.
6. Withdraw the temporary boring casing concurrently with concreting to the instructed level.
7. After hardening, break out the top section of the concrete pile to reach sound concrete.

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.

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 100 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 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	400 mm diameter 600 mm diameter 750 mm diameter 900 mm diameter

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	instruments as necessary but excluding concrete & reinforcement etc. all complete as per drawing, specification and direction of Engineer-in-Charge.	1000 mm diameter 1200 mm diameter 1500 mm diameter

B) 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 6 metres, centre to centre (Or as directed by the Engineer).

C) Temporary Casings

Temporary casing of approved quality or an approved alternative method shall be used to maintain the stability of pile excavations, which might otherwise collapse.

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.

D) Stability of Pile Excavation Using Drilling Fluid

Where a borehole is formed without casing under water or using drilling fluid for maintaining the stability of a boring, the level of the water or fluid in the excavation shall be maintained so that the water or fluid pressure always exceeds the pressure exerted by the soils and external ground water. The water or fluid level shall be maintained at a level not less than 2 metres above the level of the river water level or any artesian pressure level.

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.

E) 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

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approved dumping areas on land. The Contractor shall be fully responsible for costs involved in removing the excavated material to spoil.

F) 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.

G) 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.

H) 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.

I) 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.

J) 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.

K) 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.

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.



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.

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.

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:

- 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. 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 spoon sampling, 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

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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
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	Linear Metre

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	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)	
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 square precast concrete piles shall conform to the general requirement for concrete formwork as described in Section 5.1.

The head of each square 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.

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. 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.

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.

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 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 an approved sequence to minimize the detrimental effects of heave and lateral displacement of the ground.

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.

4.2.6 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 shall be measured in accordance with Specifications Section 5.2.4.

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, 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:

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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
	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 80 (550 MPa) Deformed Steel Reinforcing Bars	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
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

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 expanses 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

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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. A proof load should not normally exceed 200% of the working load on a pile except in circumstances where Special Provisions are provided for the testing of precast piles driven to a set. In these circumstances, 300% is specified.

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**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.

Table 4.4-1

Loading Sequence			
Load as Percentage of Working Load		Minimum Time of Holding Load	
Bored Piles	Driven Piles		
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 1.5 times of the working lateral load 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-in-charge.

Before commencing load test, Contractor shall submit methodology for conducting load test to the E-I-C 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)

4.4.17 Measurement and Payment

Load tests on large diameter (i.e. exceeding 1.2 metre) cast in place bored piles shall normally be carried out on working piles using other working piles as anchor piles. 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 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:

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04/04/01(a)	Load Test on Cast in Place Working Pile (Proof load to be specified in BoQ) 50 Ton	Number
04/04/01(b)	Load Test on Cast in Place Working Pile (For 100 Ton)	Number
04/04/01(c)	Load Test on Cast in Place Working Pile (For 200 Ton)	Number
04/04/01(d)	Load Test on Cast in Place Working Pile (As specified in Drawings & BoQ)	Number
04/04/02	Load Test on Cast in Place Pilot Pile (Proof load to be specified in BoQ)	Number
04/04/03	Load Test on Pilot Driven Pile (Proof load to be specified in BoQ)	Number
04/04/04	Lateral Load Test	
04/04/04(a)	Lateral Load Test (Up to 50 MT capacity pile)	Number
04/04/04(b)	Lateral Load Test (Above 50 MT capacity pile)	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.

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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

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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.

- 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
		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 mix not leaner than 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.

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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.

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 REGARDI NG OBSTACL ES OR SAND BELOW DURING SINKING	REPORT ANY SPECIAL METHOD OF SINKING EMPLOYE D	REMARKS	SIGNATU RE OF SUPERVIS ING 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.7 COL.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.
- 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

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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 STEINING	TOTAL SINKING	REDUCED LEVELS (RL'S) OF GAUGE MARKS						TILT			SHIFT			ACTION TAKEN FOR RECTIFI CATION	REMARKS	SIGNATURE OF SUPERVISIN G OFFICER
			ALONG X-AXIS			ALONG Y-AXIS			TILT ALONG X- AXIS	TILT ALONG Y- AXIS	RESULTANT TILT (COL10 ² +COL11 ²) ^{1/2}	ALONG X-AXIS WITH DERECTION	ALONG Y-AXIS WITH DERECTION	(COL13 ² + COL14 ²) ^{1/2}			
			(PLACE) END	(PLACE) END	DIFFERENCE (COL-5- COL-4)	(U/S)	(D/S)	DIFFERENCE (COL-8- COL-7)	COL-6 DIVIDED BY WELL DIA	COL-6 DIVIDED BY WELL DIA							
			METRE	METRE	METRE			METRE				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.
- f)

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.
- 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

DIVISION 4 - FOUNDATION WORK

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

Pay items shall be:

04/07/01	Cutting Edge (Well Shoe)	Ton
04/07/02	Class-20 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

DIVISION 4 - FOUNDATION WORK

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 specified otherwise, all steel for sheet piles shall be manufactured to ASTM, BSTI (BDS ISO) or any other equivalent standards.

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 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.

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	$\pm 2\%$
	b) Interlocked piles	$\pm 3\%$
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	$\leq 2\%$
	b) perpendicular to line of wall	≤ 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.

Pay Item shall be:

Pay Item No.	Description	Unit Measurement
	Setting Sheet Piles (temporary)	Tonne
	Setting Sheet Piles (Re-used) (Temporary)	Tonne
	Setting Sheet Piles (Permanent)	Tonne
	Setting Sheet Piles (Re-used) (Permanent)	Tonne

4.9 REINFORCED EARTH WALLS

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.

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.

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.

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) / CE Certification 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.
 - fs - 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 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 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 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 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.

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 roadlevel 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) 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

(iii) 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 fascia 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.

(iv) 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, geo-composite drain of specifications mentioned as per Clause of RHD specifications shall be adopted.

(v) 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	~ 2%	± 100mm

	considerations		

4.9.4 Measurement and Payment

The unit of measurement for furnishing and fabricating the materials for the RE walls, including concrete facing panels, soil reinforcements, attachment devices, fasteners, bearing blocks and shims, 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.

Pay Item shall be:

Pay Item No.	Description	Unit Measurement
XXXXXXX	Reinforced Earth Wall	sqm
XXXXXXX	Earth fill for RE Wall	Cubic meter

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)

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
Xxxxxxxx	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
xxxxxxx	Supplying, handling, transporting, pitching and driving piles	Liner meter

4.12 LATERAL LOAD TEST

4.12.1 Description

This Work shall consist in performing Lateral Load Test on Pile in conformance with ASTM 03966 or equivalent standard as approved by the Engineer. Any alternate test methods proposed by the contractor shall be at the discretion of the Engineer and within stipulated costs and will have to be prior approved before commencement of work.

4.12.2 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, 2022 or other applicable standards and methods acceptable to the Engineer.

4.12.3 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 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.

4.12.4 Measurement and Payment

Lateral Load Test shall be measured in number of Lateral Load Tests completed and accepted by the Engineer.

The payment shall be the full compensation for furnishing all labor, materials, and equipment necessary to satisfactorily complete the work including everything to assemble, install, conduct and remove the lateral load test equipment, as well as all report preparation, costs associated with the procurement, fabrication, and installation of the test piles including procurement and installation of the instrumentation.

Pay Item No.	Description	Unit Measurement
xxxxxxx	Lateral Load Test	Nos.

4.13 PARALLEL SEISMIC TEST

4.13.1 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.

4.13.2 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

4.13.3 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 hydrophone is 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	

4.13.4 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
xxxxxxx	Parallel Seismic Test (PST)	Nos.

4.14 HIGH STRAIN DYNAMIC TESTING OF PILES

4.14.1 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.

4.14.2 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.

4.14.3 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.

4.14.3 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
xxxxxxx	High Strain Dynamic Test (HSDT)	Nos.

4.15 ULTRASONIC CROSS-HOLE TESTING

4.15.1 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.

4.15.2 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)

4.15.3 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).

4.15.4 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
xxxxxxx	Conduction of Cross-hole sonic load test on xxx diameter pile including reporting of the results	Nos

DIVISION 5 STRUCTURES



DIVISION 5 - STRUCTURES

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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	-

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 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

A) 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 Characteristic Strength		Nominal Maximum	Minimum
	(N/mm ² @ 28 days)		Size of Coarse Aggregate	Cement Content
Concrete	Cylinder	Cube	(mm)	(Kg/m ³)
Class	(150 x 300 mm)	(150 mm)		
10	10	13	40	210
			20	240
15	15	19	40	250
			20	280
20	20	25	40	300
			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.**

B) Proportioning

When designing the concrete mix, the Contractor shall consider the following conditions:

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.

C) 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.

The Contractor shall thus at his own discretion establish additional testing procedures as necessary.

B) Control of Concrete Production

1) Materials

Materials used shall be tested in accordance with Section 5.1.2.2.

2) 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.

3) 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

1) 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.

2) 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.
- 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:

- 1) 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
- 2) 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

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.

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 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.

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 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.
- 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 and 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.
- 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 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 centre of the span and working from the centre 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.

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 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. 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 immediately 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.

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.

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.

B) Definition of Terms

- 1) Admixture. Any material added to the grout other than Portland cement and water.
- 2) Duct. The hole or void provided in the concrete for the tendon used in post-tensioning, formed by sheathing.
- 3) Grout. A mixture of cement and water with or without admixtures.
- 4) Grout opening or vent. An inlet, outlet or vent in the duct for grout, water or air.

C) 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.

D) 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.

E) 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 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.

F) 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.

G) 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.
- 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.

H) 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 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.

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 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
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:

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, $f_u(R_m)$ 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, $f_u(R_m)$ 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/ BDS ISO 14654: 2013 specification for a coating thickness (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 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.

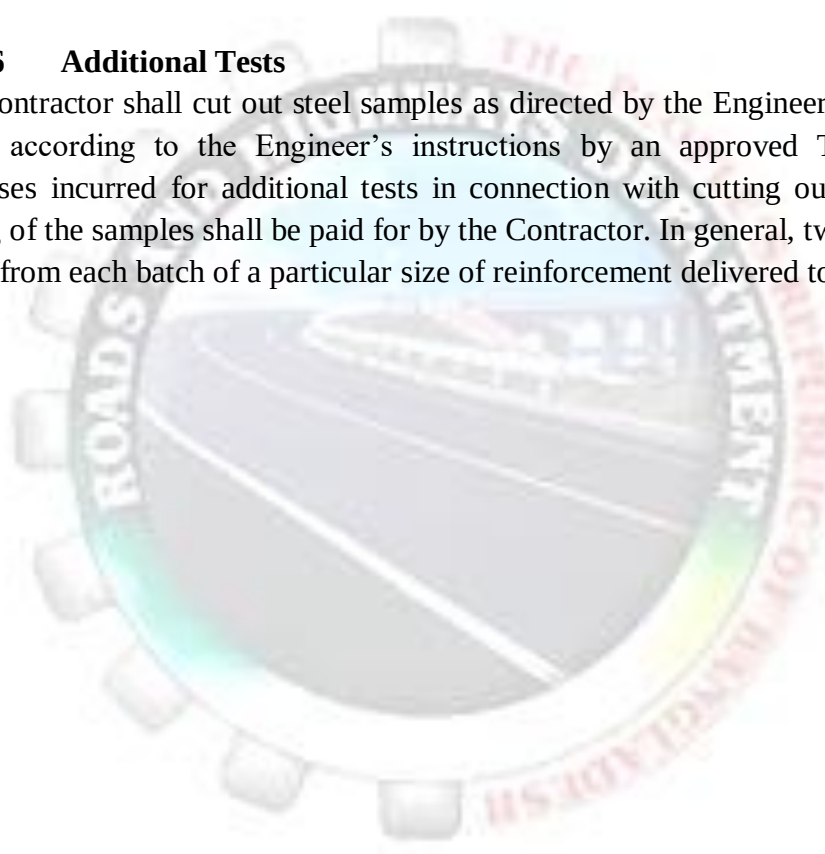
5.2.2.5 Ordering Material

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 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 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) 05/02/02(h)	FBECR : Extra cost for FBEC over item 05/02/02(a) to 05/02/02(e) For Re-bar diameter: 8mm to 12mm For Re-bar diameter: 16mm to 50mm	Tonne Tonne
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.

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.

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

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.

B) 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.

C) 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

- 1) 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.
- 2) Tensioning shall be carried out only in the presence of the Engineer unless permission in writing has been obtained to the contrary.
- 3) 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.
- 4) 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.
- 5) 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.

- 6) The Contractor shall establish the datum point for measuring extension and jack pressure to the satisfaction of the Engineer.
- 7) 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.
- 8) 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%.
- 9) 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 tendon. 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.

- 10) 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.
- 11) 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.
- 12) 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.
- 13) 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.
- 14) 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

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 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 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:

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 Materials

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 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 x 115 mm x 70 mm. Picked Jhama bricks may have dimensions slightly below those for other brick but not less than 235 mm x 110 mm x 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 close 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.

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 works.

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:

- 1) Foliage Green Bridge Paint M 67
- 2) Black Bridge Paint M 68
- 3) Aluminium Paint (Paste-Mixing Vehicle) M 69
- 4) 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

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:

- 1) Oil, grease and similar adherent matter shall be removed by washing with a suitable solvent. Excess solvent shall be wiped from the work before proceeding with subsequent operations.
- 2) The surface to be painted shall be cleaned and dehydrated (free of occluded moisture) by the passage of oxyacetylene flames which shall have an oxygen to acetylene ratio of at least one. The inner cones of these flames shall have a ratio of length to port diameter of at least 8 and shall be not more than 3.7 mm centre to centre. The oxyacetylene flames shall be traversed over the surfaces of the steel in such manner and at such speed that the surfaces are dehydrated; and dirt, rust, loose scale in the form of blisters or scabs, and similar foreign matter are freed by the rapid, intense heating by the flames. The flames shall not be traversed so slowly that loose scale or other foreign matter is fused to the surface of the steel. The number, arrangement and manipulation of the flames shall be such that all parts of the surfaces to be painted are adequately cleaned and dehydrated.
- 3) Promptly after the application of the flames, the surfaces of the steel shall be wire brushed, hand scraped wherever necessary, and then swept and dusted to remove all free materials and foreign particles. Compressed air shall not be used for this operation.
- 4) Paint shall be applied within 2 hours after the steel has been cleaned and while the temperature of the steel is still above that of the surrounding atmosphere, so that there will be no re-condensation of moisture on the cleaned surfaces.

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

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

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.

- SA – 1, Light blast cleaning: Through this process of cleaning, there it could be done 20 micron to 39 micron thickness of coating.
- SA – 2, Thorough blast cleaning: Through this process of cleaning, there it could be done 39 micron to 59 micron thickness of coating.
- 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.
- 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 an airless spray-gun. When applying contents by spraying it must only be thinned by Mineral Spirit or Aromatic hydrocarbon/appropriated 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 contaminations.

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
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.

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.

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.

- 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.
- c) 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.
- c) The movement capacity of deck expansion joints shall be as shown on the Drawings.

5.8.2.4 Storage of Materials and Protection against Corrosion

The Contractor shall propose the corrosion protection system for components of movement joints, full details of which shall be submitted for the approval of the Engineer. All materials for movement joints delivered to site shall be stored under cover, on platforms above the surface of the ground, to the satisfaction of the Engineer. They shall be kept free from dirt, oil, grease and other foreign substances. Any materials unused prior to the manufacturer's "use by" date shall be removed from site by the Contractor, unless written approval to the contrary is obtained from the Engineer.

5.8.2.5 Construction Methods

All materials and fabrications shall be installed in accordance with details shown on the Drawings and where applicable, in accordance with the manufacturer's instructions and recommendations. The joint gap and pre-setting to suit ambient temperatures at the time of installation shall be as directed by the Engineer.

- a) Not less than 30 days prior to placing an order for a proprietary joint, of 60 days before commencing installation of the deck joints, the Contractor shall submit for approval, complete shop drawing showing details of fabrication and installation.
- b) Expansion deck joints as shown on the Drawings have been located on the bridge decks showing the longitudinal movement in the bridge decks due to shrinkage, creep and thermal effects in either the precast beams or the concrete deck slab as zero. The Contractor shall take into account at the time of installation of the deck joints the actual movement that has taken place in the bridge deck and shall take such measures as directed by the Engineer to ensure that the deck joint openings as installed are satisfactory.
- c) Joints shall be of uniform width and shall be accurately set, finished and aligned flush with the finished carriageway level to provide a smooth ride free from tyre slap and impact loading, all to the satisfaction of the Engineer.

5.8.2.5 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

5.8.2.6 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.

5.8.2.7 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

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 a 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 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 centres 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.

Pay item shall be:

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, Grade 36 or ASTM A611, 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 Method B.

Table 5.11.2.3

Test Method	Properties of Elastomer	unit	Type A	Type B	Type C

D2240 D412	Physical Hardness(shore a Durometer) Minimum Tensile Strength Minimum Ultimate Elongation	IRHD N/mm ² /MPa	50+5 15.52 400	60+5 15.52 350	70+5 15.52 300
D573	Accelerated Ageing(70 hours at 100 dc +1dc) Maximum Change in Durometer Hardness Maximum change in Tensile strength Maximum change in Ultimate elongation	IRHD % %	15 -15 -40	15 -15 -40	15 -15 -40
D395 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 D 297	Ash Content	%	5	5	5
ASTM D 4014	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.

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:

<u>Bearing</u>	<u>Rate of Testing</u>
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 ± 3 mm). 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 ± 1 mm 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

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) 300mm x 400mm x 72mm
- b) 400mm x 500mm x 72mm
- c) 450mm x 500mm x 72mm
- d) 500mm x 500mm x 72mm

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:-

- (a) Equal or better load carrying and movement capacity;
- (b) Fabricated by an approved manufacturer;
- (c) All control dimensions are maintained ; no change in overall height; bearing must fit within limits of detailed masonry plate;
- (d) Use unfilled **Polytetrafluoroethylene (PTFE)** ;
- (e) Use elastomeric material as a confined medium within the pot;
- (f) 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 grade steel specified above with the additional requirements that the steel shall contain 0.35 to 0.5% copper to enhance its weathering characteristics.

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

Filler material, when used, 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 + 47 ⁰C. It shall not change its consistency or affect the constituent parts of the bridge bearings. The lubricant shall have the following properties:-

- (i) Worked penetration range of 240 to 280 determined in accordance with BS 5296
- (ii) a solidification point < A40 ⁰C
- (iii) a bleeding < 4% when tested in accordance with BS 5297 using 150 ⁰C for 24 hour.

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

		Type A	Type B	Type C	Methods of Tests
1	Nominal Hardness (IRHD)	46 to 55	56to 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
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 impose 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, BS4551 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.
- (ii) 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
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;
- (k) 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 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

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:-

(i) 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.

(ii) The coefficient of friction shall be calculated as (maximum horizontal force) / 22x vertical load for each test position and shall in no case exceed Table 2.11-2

(iii) 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

- (iv) 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 type 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 Part 1, 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 design 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 tests 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.

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 it's 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.

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 D5977-15: 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 (500mm X 500mm X 72mm)	Number
05/12/01(b)	Supply and Installation of Pot bearings (500mm X 450mm X 72mm)	Number
05/12/01(c)	Supply and Installation of Pot bearings (400mm X 300mm X 72mm)	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
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

This work will be paid for at the contract unit price each for jack and remove existing bearings.

xxxxxxx	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
- 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 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 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.

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 : ± 5 mm to bottom slab for box girders, top and

bottom flange for T-girders and slabs

- 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

Cast In-Situ Superstructure

- a) Variations in thickness of top and : -5 mm to +10 mm bottom slab for box girders, top and bottom flange for T-girders and slabs
- 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

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
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

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	
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:

1. 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.
2. Positioning, use and sequencing of falsework, jacking and/or releasing of falsework, temporary towers, supports, tie-downs, counterweights, closure devices and the like.
3. 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.

4. 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.
5. Stressing forces and elongations for post-tensioning.
6. Sequencing of filler injection operations.
7. 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.
8. 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).

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) and ii) are mandatory while iii) and iv) are related to categories defined in ISO 15835-1 Sec 5.2

i) 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 $R_{m_{spec}}$ 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.

ii) 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.

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.

iii) 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.

iv) 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:
 $R_m, \text{spec or } ReH \times (R_m/ReH)_{\text{spec}}$

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

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.

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

(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 manner in which 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

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.

5.18.4 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).

5.18.5 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





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% Khoa 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 surface has 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 technician 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 crack 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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7.1 TRAFFIC SIGNS

7.1.1 General

The color, configuration, size and location of all traffic signs for the District Highways, Regional Highways, National Highways, and Expressways shall be as specified in the drawings and relevant Specifications or as directed by the Engineer. Specified traffic sign shall be in accordance with the Road Safety Engineering Manual of Roads and Highways Department or as shown on the drawings.

Where the competent authority advises to make the meaning of a sign or symbol more explicit or in the case of mandatory signs limits 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 definition plate of suitable size. The definition plate shall be retro-reflective with color-code provided in Road Safety Engineering Manual of Roads and Highways Department. Numerals and word messages shall be in Bengali and English languages as necessary.

Solar Road Signs

Solar Road Signs can play a vital function in a modern, advanced traffic management system. These signs are strongly illuminated and therefore easy to read, making them much more suitable for the purpose of ensuring the attention of road users. In addition, solar road signs have considerable benefit of conserving energy due to its environmentally conscious solar technology.

Signs must be used where they are required. Warning signs has to be placed during ongoing road works and then removed to use in required location without disrupting movement on nearby footpaths. The speed sensors built into most solar powered road signs are very sensitive and so it has to be assured that the solar power is only used when traffic is on the road. In the period when the traffic flow is smooth, the sign is not illuminated and therefore uses no power.

Signs are also used for indicating to the drivers about road condition through flickering automatically and warn the drivers to be carefully. They help to reduce the traffic accidents and fatalities. Signs are mainly used at rural-urban fringe zone and in locations where the sunshine is strong.

Solar traffic flash light can also be used as indicator in the central divider edge between the normal & express lane. It would give the flash warning light at night capturing the driver's attention reducing the possibility of vehicles collision and also act as a warning system for pedestrians.

(a) Informatory, cautionary and mandatory signs

Informatory, cautionary and mandatory signs shall be manufactured using layout method with inscriptions or cut letters with colored retro reflective sheeting on different types of road in accordance with **Road Safety Engineering Manual of Roads and Highways Department.**

(b) Overhead signs

Overhead signs may be used instead of or in addition to kerb mounted signs in places where the situation warrants in order providing 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
- Three or more lanes in each direction
- Restricted sight distance
- Closely spaced interchanges
- Multi-lane exits
- Large percentage of commercial vehicles
- High speed vehicular movement
- Insufficient space for 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 bridge structures. Where these are required to be provided at some other locations, the support system should be properly designed based on sound engineering principles, to safely sustain the dead load, live load and wind 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, walkway loading of 250 kg concentrated live load shall also be considered for the design of the overhead sign structure. The height and lateral offset will be provided as per Road Safety Engineering Manual of Roads and Highways Department.

Number of Signs at an Overhead Installation

In no case shall there be more than three signs displayed at any one location, including regulatory or warning signs, either on the overhead structure or on its support.

7.1.2 Materials

7.1.2.1. Sign Posts

Contractor shall provide all Sign Posts sufficiently strong enough so that the signs can withstand in all conditions and even against strong wind during storm. Mounting post for signs shall be in the standard form of heavy galvanized round steel tubes of not less than 50 mm internal diameter or 75 mm external diameter with minimum 2 mm wall thickness or other approved sections of adequate tensile, bending, compression strength and impact, hardness and torsional rigidity, complying with the appropriate specifications (ASTM A370, A938) of the American Society for Testing Materials.

When necessary, due to sign board area additional posts or vertical backside supports must be used to ensure required strength against wind pressure. The stresses generated in the post due to a wind pressure of 150 kg per square meter on the sign face shall not exceed the allowable working stresses in the tube material.

The portion of the mounting post lying within ground and 0.20 meter above ground level shall be given protective bituminous coating both inside and outside. Hollow posts or other hollow sections used as mounting post shall be provided with post caps of approved cast or sheet metal or a suitable weather resisting plastics material.

7.1.2.2. Sign Plates

Sign plates and supplementary plates, on which reflective sheeting will be placed shall be manufactured from aluminum sheet, complying with BS1470 or ASTM B209 or equivalent internationally recognized specification acceptable to the Engineer. The minimum thickness of the plate shall be 2 mm.

Sign plates and panels shall be accurate to the shapes and sizes specified in the Engineering **Drawings read in conjunction with BRTA Traffic Signs Manual, March 2000**. All mounting holes shall be accurately located and, after drilling or punching, all burrs, rough spots and loose material if any must be removed. In place where painting is required, all holes shall be drilled before the painting is applied.

7.1.2.3. Frames and Stiffening

Sign plates requiring frames or stiffening shall have adequate ribs or flanges as an integral part of the sign plate or shall be provided with frames or stiffening members. The metal used for frames and stiffening shall be mild steel with proper protective painting for corrosion resistance or otherwise be compatible with the metal used for the face plate so as not to cause corrosive activity (aluminum or stainless steel frame is recommended for aluminum plates). Except where ribs or flanges are integral parts of the sign plate and

provide the necessary stiffening, sheet metal sign plates exceeding 500 mm in any dimension shall be stiffened by the attachment of a frame or stiffening member (s) to the back of the sign plate. The frame or stiffening members shall be corrosion resistant, and made of a material which does not affect adversely the serviceability or durability of the sign plates.

The frame for a sign plate shall be simple and easy to fabricate and erect but shall provide required stiffness. Frame of a sign plate shall have form of flanges round the edges of a sign, welded ribs and made of steel or aluminum sections compatible with the type of the material used for the sign plate itself, with a minimum thickness of 3 mm. Where flanges are provided, they shall be uniform on all edges of the sign plate.

Where metal frame members join, these shall be welded or joined with suitable brackets, bolt and rivets. For welding of steel, AWS D1.1/D1.1M: Structural Welding Code – Steel, and for welding of aluminum plates and frames, AWS D1.2/D1.2M - Structural Welding Code for Aluminum by American Welding Society (AWS) shall be followed. Direct welding between steel and aluminum is generally avoided due to technical difficulties and the resulting weak joint. In all cases the joints shall be strong enough to withstand the stresses occurs therein due to a wind pressure of 150 kg/m^2 acting in any direction on the sign face.

7.1.2.4. Fixture and Fittings

The method of fixing sign plates, frames and brackets to posts shall be such that will facilitate their removal for replacement or maintenance purposes and at the same time ensure that the sign and any framing shall be held firmly enough to withstand the specified loads. Signs mounted on single posts shall be so fixed as to prevent the forced rotation of the signs on the posts. Clips and brackets shall be shaped to secure a firm hold on the post without placing any bending strain on the sign plate.

Where dissimilar metals will be joined together, precautions shall be taken to prevent any electrolytic action leading to galvanic corrosion, differential thermal expansion and melting points, formation of intermetallic compound etc. Alternative to welding joint, different adhesive bonding, or using bimetallic transition inserts shall be considered to achieve a strong, reliable connection between dissimilar metals like steel frames and aluminum plates. In the case of mechanical fastening (bolts, screws, rivets, or other fasteners), such issues shall be overcome by using paint, lacquer or other suitable means to eliminate metal to metal contact. A suitable alternative for such jointing would be the combined use of riveting and adhesive (where adhesive alone may not be sufficient).

Brackets used in erection of signs, may be manufactured from sheet or cast or extruded aluminum, alloy, or may be fabricated from steel sections taking into account compatibility with sign plate materials so as not to cause corrosion. The minimum thickness of material for brackets shall be 3mm. Welded joints (if used) shall be sound, with smooth surfaces.

Holes shall be drilled before painting and shall be accurately located. Steel or aluminum strip used for clip shall not be less than 2 mm thick.

Screws and bolts shall not be less than 8 mm (5/16 inch) in diameter and of adequate length, but without excessive projection of the screwed ends. In a situation where the entire assembly would be insecure for absence of a screw, these screws shall have at least four full threads protruding when it is tight and shall be fitted with a locknut.

Where hollow rivets are used to connect sign plates to frames or fixings, the holes shall be effectively blocked to prevent light shining through. Screw, bolt or rivet heads on the face of a sign shall be unobtrusive and each shall match the color of the part of the sign where it is located.

Caps for posts of hollow section shall be shaped to shed rainwater to the outside of the posts and adequate means of securing the caps to the posts shall be provided.

The material, forms and arrangements of fixtures and fittings shall be submitted by the contractor and agreed to by the Engineer as part of the prior approval of sign fabrication.

7.1.2.5. Preservatives, Paints and Finishes for Posts and Fittings

Exposed steel surfaces shall be painted with an anti-corrosive primer as approved by the Engineer. All coatings, paints, varnishes and enamels used in the preparation and finish of the posts and fittings shall be of the best quality and made for the purpose intended to serve, and of brands and types acceptable to the Engineer. To ensure compatibility, primers, undercoats and finishing coats shall wherever possible, be of the same manufacture. All materials shall be stored and used within such time limits, as specified or recommended by the manufactures or in accordance with the directions of the Engineer.

For longer durability, especially against corrosion, all steel parts used shall have zinc coatings (hot-dip galvanizing, thermal spray, zinc-rich paints) which shall comply the coating thickness, performance requirements, and applicability requirements with ASTM Specification A 123 (for larger steel products and components like column, beam, plates etc.) or A 153 (for smaller hardware and fasteners), as appropriate. Such zinc coated parts shall not require painting unless indicated in the drawings. Where painting of steel parts is required, the paint shall be of high zinc oxide content coating material of approved formulation coating material. The color of the primer shall be different from those of succeeding coatings. Alternatively, epoxy paint with UV-resistant top coat can be considered for high durability against corrosion (ASTM D 1763 – 00 can be followed for required tests).

If painting of aluminum alloy parts is noted in the drawings, the priming paint shall be pigmented with chromates or chromes (excluding lead chromes). No painting shall be done on sign faces.

7.1.2.6. Traffic Signs having Retro-Reflective Sheeting

General requirements: The retro-reflective sheeting used on the sign shall consist of the white or other colored sheeting having a smooth outer surface which 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, and pitting, blistering, edge lifting or curling and shall have negligible shrinkage or expansion. A certificate of having tested the sheeting as per ASTM D 4956-09, for co-efficient of retro-reflection, day/night time color luminous property, outdoor weathering, shrinkage, flexibility, linear removal, adhesion, impact resistance, specular gloss and fungus resistance and its having passed these tests shall be obtained from a reputed or Government Laboratory, by the manufacturer of the sheeting.

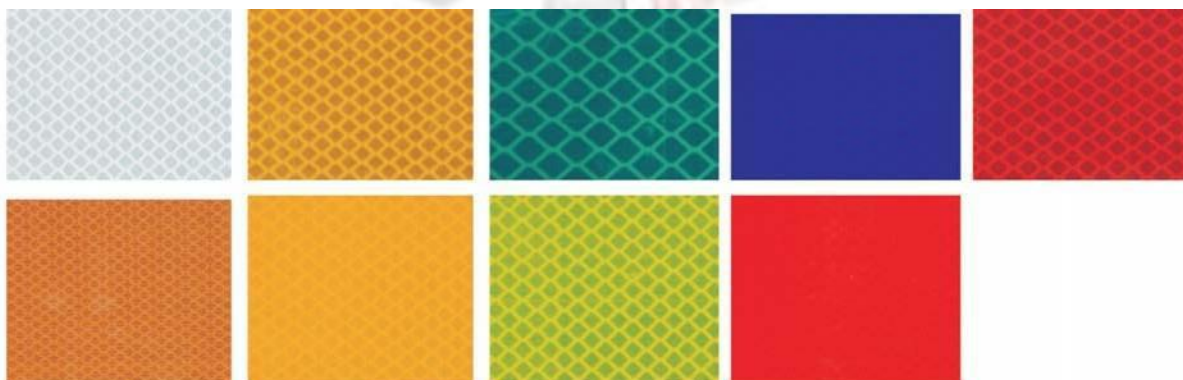
Retro-reflection Requirements:

The requirements for classes, types, coefficient of retro-reflection, applicability, warranty periods with minimum retention of coefficient of retro-reflection of retro-reflective sheeting on different types of highways shall be followed from the Highway Safety Engineering Manual 2024.

Color:

Unless otherwise specified, the general Color scheme and properties shall be as stipulated in ASTM 4956–16(b). The Colors shall be durable and uniform in acceptable hue when viewed in day light or under normal headlights at night and in inclement weather conditions. The indicative pictorial depiction is given in Table 7.1-3.

Table 7.1-3 Indicative Pictorial Depiction of Colors for Sheeting



Adhesives:

The sheeting shall have either a pressure-sensitive adhesive of the aggressive-tack type requiring no heat, solvent or other preparation for adhesion to a smooth clean surface, or a tack free adhesive activated by heat, applied in a heat- vacuum applicator, in a manner recommended by the sheeting manufacturer. The adhesive shall be protected by an easily removable liner (removable by peeling without soaking in water or other solvent) and shall be suitable for the type of material of the base plate used for the sign. The adhesive shall form a durable bond to smooth, corrosion and weather resistant surface of the base plate such that it shall not be possible to remove the sheeting from the sign base in one piece by use of sharp instrument. In case of pressure-sensitive adhesive sheeting, the sheeting shall be applied in accordance with the manufacturer's Specifications. Sheeting with adhesives requiring use of solvents or other preparation for adhesive shall be applied strictly in accordance with the manufacturer's instructions.

Messages/borders:

The messages (legends, letters, numerals etc.) and borders shall either be screen-printed or of cut-outs from durable transparent overlay or cut-out from same type of reflective sheeting (excluding for black Color) for the cautionary/ mandatory signs. Screen printing shall be processed and finished with materials and in a manner specified by the sheeting manufacturer. For the information and other signs, the messages (legends, letters, numerals etc.) and borders shall be cut-out from durable transparent overlay film or cut out from same reflective sheeting only. Cut-outs shall be bonded with the sheeting in the manner specified by the manufacturer. Both the screen-printed areas and cut-out messages sheeting and cut-out durable transparent overlay film shall be covered under the warranty period of the sheeting type, issued by the sheeting manufacturer.

Refurbishment:

Where existing signs are specified for refurbishment, the sheeting shall have a semi-rigid Aluminum backing or materials as per Clause 7.1.2, pre-coated with aggressive-tack type pressure sensitive adhesive. The adhesive shall be suitable for the type of material used for the sign and should thoroughly bond with that material.

7.1.3 Sign Fabrication and Installation

Sign Fabrication

The contractor shall submit on site sign drawings with design calculations and details of 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 and fixtures, etc. can be assembled and erected without requiring modification during installations. The installation of signs shall not interfere with traffic movement and safety including foundations for sign posts.

If desired by the Engineer the contractor will arrange at his own cost practical demonstration of the proposed fabrication process. The Engineer will accord approval of the proposed fabrication process in writing if the fabrication process becomes satisfactory to him. After getting approval of the Engineer in writing only, the contractor shall immediately start fabrication of all the signs.

Mounting Posts and Foundations

Sign posts 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 sign posts shall be fixed based on the size of the signs. The sign posts shall be made of steel tube or mild steel sections or as approved by the Engineer. The posts shall be adequately strong enough to withstand a wind pressure of 150 kg per square meter on sign face. If necessary additional posts or vertical backside supports must use on sign boards to ensure strength against wind pressure.

The lengths of posts shall be provided as shown in the 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 the drawing.

For a wind speed of 50 meters per second across the sign plate, factor of safety for the integrity and stability of the sign post-foundation shall not be less than 1.5.

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.

For the case of signs having areas of more than 2.0 square metre, the contractor shall submit, prior to start of the foundation works of the signs, design calculations to the Engineer for approval.

Embedment of Sign Posts in Concrete Foundations

The base of posts shall be embedded in concrete foundations. Concrete shall be rammed round 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 drawings or as directed by the Engineer based on specific design consideration 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 round 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.

Installation of LED solar signs

Sign Fabrication and Installation will be same as to the Sign Fabrication and Installation section under Traffic Signs having Retro-Reflective Sheeting but note that due to having solar panel, Retro-Reflective Sheeting is not required.

Major steps of installations of LED solar signs shall be -

- a) To embed the T-shaped screw into lead rail, to vise the poling tighter with anchor ear, to hold the T-shaped screw with the nut, to fix the LED traffic signal, and to connect to the solar panel.
- b) To turn on the power switch ensuring the signal work well: to cover the solar panel with covering to test the night-condition, then if LED sign is flickering well, put the covering away and test whether flickering stops in day-control.
- c) To adjust the angle and direction of the solar panel. 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°.
- d) In city areas, solar products shall not be installed under high building and shade, as the solar panel will not work, if it shade a part. ideally, solar products shall be installed in the place where the sun shine strongly.

Care and Cleaning

- a) Clean the solar panel every three months to make sure it absorbs the sunshine well.
- b) Clean the reflective sheeting and LED snoot to make sure it is clear to be seen.
- c) Turn off the power switch in order to protect the battery in long rainy days until the battery have reserved 80% capacity after three-days charging.

7.1.4 Overhead Sign Materials

Aluminum alloy or galvanized steel to be used as truss design supports shall conform to relevant ASTM/BS standards. These shall be of sections and type as per structural design requirements as shown on the plans.

After steel trusses have been fabricated and all required holes punched or drilled on both the horizontal truss units and the vertical and support units, they shall be galvanized in accordance with this Specification.

Where Aluminum sheets are used for road signs, they shall be of smooth, hard and corrosion resistant Aluminum alloy conforming to ASTM/BS standards. The thickness of sheet shall be related to the size of the sign with minimum thickness of sheet as 1.5 mm.

Plates and support sections for sign posts shall conform to section 7.1.2.

The overhead signs shall be of micro prismatic retro reflective sheeting (Type-XI).

Size and Locations 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 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.

7.1.5 Installation of Overhead Sign

The supporting structure and signs shall be fabricated and erected as per details given in the 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 foundation for sign supports including excavation and backfill, forms, steel reinforcement, concrete and its placement shall conform to the relevant Specifications given in **this** Chapter . 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 obtained by rotating the front lower edge of the sign forward. All brackets shall be of a length equal to the heights of the signs being supported.

Before erecting support structures, the bottom of each base plate shall be protected with an approved material which 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 aluminium trusses, 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 aluminium nut.

All nuts on galvanized steel trusses, with the exception of high strength bolt connections, shall be tightened only to a snug condition.

Field welding shall not be permitted.

After installation of signs is complete, the sign shall be inspected by the Engineer. If specular reflection is apparent on any sign, its positioning shall be adjusted by the Contractor to eliminate or minimize this condition.

Warranty for solar panel

- a) Solar panel lifetime should be more than 10 years
- b) Battery should be High temperature resistant lead-acid maintenance-free
- c) battery lifetime should be more than years
- d) Other parts warranty may differ from product wise
- e) Should be provided according to authority requirements.

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 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

The work shall include the supplementary plate, aluminum back plate/primary sign(s), conforming classes and types of reflective sheeting as per highway categories on sign faces, posts (also additional axes or vertical supports if required), foundations, bracings, erection and fixing in position inclusive the costs of necessary steel/aluminum frames, support structures and fittings & fixtures, etc.. Traffic signs shall be measured in numbers (standard size traffic signs) and in square meters (bigger signs than standard size).

7.1.8 Payment

Cost of Traffic Signs, measured as above, shall be paid in the following pay items. The rates of traffic signs shall comprise costs of construction, erection and mounting posts vertically in cement concrete (1:2:4) foundation, costs of primary sign, supplementary plate, posts, foundation, backing aluminum plate, sign facing with standard class of sheeting, fixing signs with post, enamel painting/galvanization on frames and posts, fittings & fixers, erection of overhead sign post and gantry, cost of all labor, transportation, loading/unloading, fittings & fixers, auxiliary materials, tools, equipment, excavation and backfilling and other incidentals and cost of maintenance, repair and replacement, if required, during defect liability period up to satisfaction of the Engineer.

Payable items shall be:

Pay Item	Description	Unit
7.1.1	Standard size Traffic sign 750 mm diameter, 750 mm triangle height or area up to 0.7 m ² including supplementary plate, frame, post and foundation etc.	a. Type I
		b. Type II
		c. Type III
		d. Type IV
		e. Type IX
		f. Type XI
7.1.2	Standard size Traffic sign 900 mm diameter, 900 mm triangle height or area up to 0.7 m ² including supplementary plate, frame, post and foundation etc.	a. Type I
		b. Type II
		c. Type III
		d. Type IV
		e. Type IX
		f. Type XI
7.1.3	Traffic signs and sign boards above 0.7 m ² including plate, frame, fasteners & foundation etc. `	g. Type I
		h. Type II
		Type III
		Type IV
		Type IX
		Type XI

7.1.3a	Steel for double posts		Kg
7.1.3b	Steel for one side cantilever post		Kg
7.1.3c	Steel for gantry		Kg
7.1.4	Solar Sign/Flashing light		No.

Note: "Type" indicates the selected type of retro-reflective sheeting.

7.2 REMOVAL OF EXISTING TRAFFIC SIGNS

7.2.1. Description

This work shall consist of removal of existing traffic signs. The existing unspecified / damaged traffic signs shall be removed and disposed of as per 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 its foundation and disposed off from the site. The back filling of the excavated hole shall be made with selected soils and be compacted. Unused spoils will be the property of the contractor.

7.2.3. Measurement

The measurement for removal of the traffic sign shall be in Number.

7.2.4 Payment

The work is measured above shall be paid in the following items. The payment shall be full compensation of the excavation and taking out the sign post with foundation, filling and compacting the holes with selected soil, cost of all labor, equipment, transporting the post with foundation and all other incidentals to complete the work.

Pay item shall be:

Pay Item	Description	Unit
7.2.1a	Removal of existing unspecified / damaged traffic signs on single and double posts	No.
7.2.1b	Removal of existing unspecified / damaged traffic signs on one side cantilever post	No
7.2.1c	Removal of gantry mounted existing unspecified / damaged traffic signs	No

7.3 ROAD MARKINGS

General

The color, width and layout of road markings shall be in accordance with RHD Road Safety Engineering Manual 2024, and as specified in the drawings or as directed by the Engineer.

Road markings shall be hot applied thermoplastic compound, reflectorized paint or cold applied reflective paint as specified in the item and the material shall meet the requirements as specified in these Specifications.

7.3.1 Hot Applied Thermoplastic Road Marking

General

- a) The work under this section shall consists of marking traffic stripes using a thermoplastic compound meeting the requirements specified herein.
- b) The thermoplastic compound shall be screeded or extruded on to the pavement surface in a molten state by 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 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, shall be applied to the pavement in advance of placing of the stripes to ensure proper bonding of the compound. On new concrete surface any laitance and/or curing compound shall be removed before the markings are applied.

Thermoplastic material

The thermoplastic material shall be homogeneously composed of aggregate, pigment, resins and glass reflectorizing beads.

Requirements

- a) **Composition:** The pigment, beads, and aggregate shall be uniformly dispersed in the resin. The material shall be free from all skins, dirt and foreign objects and shall comply with requirements indicated in Table 7.3-1

Table 7.3-1 Proportions of Constituents of Marking Material (Percentage by weight)

Component	White	Yellow
Binder	18.0 min.	18.0 min.
Glass Beads	30-40	30-40
Titanium Dioxide	10.0 min.	—
Calcium Carbonate and Inert		
Fillers	42.0 max.	See Note below
Yellow Pigments	—	See Note below

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.

b) **Properties** : The properties of thermoplastic material, when tested in accordance with ASTM D36/BS-3262-(Part I), shall be as below:

a. Luminance:

White: Daylight luminance at 45°-65 percent min. as per AASHTO M 249.

Yellow: Daylight luminance at 45°-45 percent min. as per AASHTO M 249.

b. Drying time:

When applied at a temperature specified by the manufacturer and to the required thickness, the material shall set to bear traffic in not more than 15 minutes.

c. Skid resistance:

Not less than 45 as per BS: 6044.

d. Cracking resistance at low temperature:

The material shall show no cracks on application to concrete blocks.

e. Softening point:

102.5°C + 9.5°C as per ASTM D 36.

f. Yellowness index (for white thermoplastic paint) :

Not more than 0.12 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 un-melted 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, trade mark or other means of identification of manufacturer
 - b. Batch number
 - c. Date of manufacture
 - d. Color (white or yellow)
 - e. Maximum application temperature and maximum safe heating temperature.
- f) **Sampling and testing:** The thermoplastic material shall be sampled and tested 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.

7.3.1.1 Reflectorizing glass beads

General:

This Specification 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 basis thermoplastic compound vide Table 7.3.2 and Type 2 beads are those which are to be sprayed on the surface.

The glass beads shall be transparent, colorless and free from milkiness, dark particles and excessive air inclusions.

These shall conform to the requirements spelt out in Clause shown below:

Specific requirements

- a. **Roundness:** The glass beads shall have a minimum of 70 percent true spheres.
- b. **Refractive index:** The glass beads shall have a minimum refractive index of 1.50.
- c. **Gradation:** The glass beads shall meet the gradation requirements for the two types as given in Table 7.3-2.

Table 7.3-2. Gradation Requirements for Glass Beads

Sieve size	Percent retained	
	Type 1	Type 2
1.18 mm	0 to 3	
850 micron	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 micron	—	0 to 15

Free flowing properties:

The glass beads shall be free of hard lumps and clusters and shall dispense readily under any conditions suitable for paint striping. They shall have to pass the free flow-test.

Test methods: The specific requirements shall be tested with the following methods:

- a. Free-flow test: Spread 100 grams of beads evenly in a 100 mm diameter glass dish. Place the dish in a 250 mm inside diameter desiccator which is filled within 25 mm of the top of a desiccator plate with sulphuric acid water solution (specific gravity 1.10). Cover the desiccator and let it stand for 4 hours at 20°C to 29°C. Remove sample from desiccator, transfer beads to a pan and inspect for lumps or clusters. Then pour beads into a clean, dry glass funnel having a 100 mm stem and 6 mm orifice. If necessary, initiate flow by lightly tapping the funnel. The glass spheres shall be free of lumps and clusters and shall flow freely through the funnel.
- b. The requirements of gradation, roundness and refractive index of glass beads and the amount of glass beads in the compound shall be tested as per BS: 6088 and BS: 3262 (Part I).
- c. 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.

Application properties of thermoplastic material

The thermoplastic material shall readily get screeded or extruded at temperatures specified by the manufacturers for 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 which are toxic, obnoxious or injurious to persons or property.

Preparation of Road Surface

The material shall be applied only on a surface, which 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 marking. Removal of old marking shall have separate pay items.

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 specified by the manufacturer and shall in no account be allowed to exceed the maximum temperature stated by the manufacturer. The molten material shall be used as expeditiously as possible and for thermoplastics which 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.

Laying

Markings may be applied by hand-screening, hand propelled machine or by self-propelled 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 manufacture's recommendation and BS 3262 as continuous or intermittent lines, arrows, figure and symbol of the types and colors and dimensions in the Drawings, or as otherwise directed by the Engineer.

Thermoplastic paint with glass beads shall be laid to the thickness.

- a. Screed line not less than 3 mm.
- b. The method of thickness measurement shall be in accordance with appendix H BS 3262.

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 marking shall be screed or spray applied in cooperating Ballotini and also has surface application of Ballotini applied evenly at the rate of $500 \pm 50 \text{ g/m}^2$. The minimum thickness specified is exclusive of surface applied solid glass beads. Road marking materials shall only be applied to surface which is clean and dry. Marking shall be free from raggedness at their edges and shall be uniform free from streaks. Carriageway lane and edge lines shall be laid by approved mechanical means to a regular alignment.

Trial area for Road Marking

The contractor shall undertake trial area of a representative sample of the road markings to demonstrate the suitability of his proposed method and equipment and the competence of his operatives 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 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 longitudinal lines shall not deviate from the true edge by more than 10 mm in 15 meter.
- 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 which 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 Drawings. Straight edges and templates shall be used if required by the Engineer.

Re-use of Thermoplastic Material

At the end of the day's work, as much as possible of the material remaining in the heater and/or laying apparatus shall be removed. This may be broken and used again, provided that the maximum heating temperature has not been exceeded and that the total time during which it is in a molten condition does not exceed the requirements.

Defective Materials or Workmanship

Materials which are defective or have been applied in an unsatisfactory manner or to incorrect dimensions or in a wrong location shall be removed, the road pavement made good and the materials replaced, reconstructed and/or properly located, all at the Contractor's expense and to the satisfaction of Engineer.

Protection of Traffic

The Contractor shall protect pedestrian, vehicular and other traffic adjacent to the working area against damage or disfigurement by construction equipment, tools and materials or by splatters, splashes and smirches of paint or other construction materials and shall during the course of the work provide and maintain adequate signs and signals for the warning and guidance of traffic.

The Contractor shall be fully responsible to ensure protection of new work till its maturity & till such time, it hardens fully to permit traffic without any damage. It is binding upon the Contractor to replace such damaged work at his own cost & responsibility.

7.3.2. Cold Applied Reflective Paint

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 brush or by Road Marker (Spray equipment capable of spraying the paint on the road). Glass beads shall be subsequently spread pneumatically on to the paint when it is still wet so that the beads will be firmly held by the paint after drying. Color of the paint shall be white or yellow as specified in the RHD Road Safety Engineering Manual 2024 or drawings or as directed by the Engineer.

Material

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 requirements indicated in Table 7.2-3

Table 7.2-3 Proportions of Constituents of Paint (Percentage by weight)

Component	White	Yellow
Binder	25.0 min.	18.0 min.
Titanium Dioxide	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 content by weight shall be a minimum of 65 percent as determined in accordance with test method ASTM D1644. The liquid paint shall have a density of 1.3 minimum as determined in accordance with test method ASTM D1475.

Appearance: Drying Time of the paint as determined by the test method ASTM D711 shall be a maximum of 20 minutes at a wet film thickness of 350 micron. The paint shall set to bear traffic after 40 minutes when the ambient temperature is higher than 24°C. The paint shall not be applied when the surface temperature of the road is higher than 40°C.

Properties of the dried paint film: When tested using a sand abrasion tester as described in ASTM D968, the quantity of sand required for removal of a 75 micron thick unbeaded dry film shall be greater than 65 liters.

Elongation: The unbeaded dry film shall pass the test in accordance with ASTM D 1737 and ASTM D 2205.

Water Resistance: The unbeaded dry film shall pass the test in accordance with ASTM D1647 and ASTM D2205.

Skid resistance: Skid resistance for the beaded dry film shall be not less than 45 as per BS 6044.

Storage life: The material shall meet the specifications for a period of one year. During this period, the paint material when stored in an airtight container shall not form skin. The material shall also not form a cake at the bottom of the container.

Minimum thickness of the Unbeaded Cold Applied Paint Coat: The minimum thickness of the wet unbeaded coat of paint shall not be less than 400 micron, and the minimum thickness of the dry unbeaded coat of paint shall not be less than 200 microns.

Retro-reflective Properties:

<i>The minimum co-efficient 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 – 100 mcd/m ² /lux after defect liability period of one year
For yellow paint (Beaded)	– 200 mcd/m ² /lux on application

	– 100 mcd/m ² /lux after defect liability period of one year
<i>The minimum luminous co-efficient 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 the cold-paint shall be clearly and indelibly marked with the following information:

- a. The name, trade/patent mark
- b. Batch No.
- c. Month of Manufacture
- d. Color (White or Yellow)

Sampling and testing

The cold applied reflective road marking paint shall be sampled and tested in accordance with appropriate ASTM/BS test methods.

The contractor shall furnish to the Engineer a copy of certified test methods from the manufacturer of cold applied reflective road marking paint showing the results of:

- a) No pick up time as per ASTM D 711.
- b) Resistance to wear as per ASTM D4060 or as per ASTM D968 from approved laboratories.
- c) Material safety data sheet shall be obtained from the manufacturer and kept with the paint materials.

Reflecting glass beads

General: Reflection is achieved by pneumatically spreading glass beads on to the paint when it is still wet. The beads will be firmly held by the paint after drying.

The glass beads shall be transparent, colorless and free from milkiness, dark particles and excessive air inclusions. These shall conform to the requirements spelt out below.

Specific requirements

a. Gradation: The glass beads shall meet the gradation requirements as per No. 4 of BS: 6088 as given in Table 7.2-4.

Table 7.2-4 Gradation Requirements for Glass Beads

Sieve Size	Percentage Retained
250 micron	0-10
150 micron	80-100
< 150 micron	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. Free flowing properties: The glass beads shall be free of hard lumps, clusters and shall dispense readily under any conditions suitable for paint striping. They shall pass the free flow-test as given below.

Test Methods: The specific requirements shall be tested with the following methods:

a. Free-flow test: Spread 100 grams of beads evenly in a 100 mm diameter glass dish. Place the dish in a 250 mm inside diameter desiccator which is filled within 25 mm of the top of a desiccator plate with sulphuric acid water solution (specific gravity 1.10). Cover the desiccators and let it stand for 4 hours at 20°C to 29°C. Remove sample from desiccator, transfer beads to a pan and inspect for lumps or clusters. Then pour beads into a clean, dry glass funnel having a 100 mm stem and 6 mm orifice. In case it is required flow can be initiated by lightly tapping the funnel. The glass spheres shall be free of lumps and clusters and shall flow freely through the funnel.

b. The requirements of gradation, roundness and refractive index of glass beads and the amount of glass beads in the compound shall be tested as per BS:6088 and BS:3262 (Part-1).

c. 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.

Application

Marking shall be done by machine. For locations where painting cannot be done by machine, approved manual methods shall be used with prior approval of the Engineer. The Contractor shall maintain control over traffic while painting operations are in progress so as to cause minimum inconvenience to traffic compatible with protecting the workmen.

The cold applied paint shall be applied on the asphalt/cement concrete road surface by brush or by Road Marker/Spray equipment capable of spraying the paint on the road surface. Glass beads @ 300gms per square metre shall be subsequently spread pneumatically on to the paint when it is still wet so that the beads will be firmly held by the paint after drying.

The pavement temperature shall not be more than 40°C during application. All surfaces to be marked shall be thoroughly cleaned of all dust, dirt, grease oils and all other foreign matter before application of paint.

The material, when formed into traffic stripes, must be readily renewable by placing an overlay of a new material directly over an old line. Such new material shall so bond itself to the old line that no splitting or separation takes place.

Cold applied paint shall be applied in intermittent or continuous lines of uniform thickness of at least 200 micron of unbeaded dry film thickness unless specified otherwise. When arrows or letters are to be provided, cold applied paint may be applied manually. In addition to the beads recommended for, a further quantity of 300 gms of glass beads per square meter conforming to the specification shall be sprayed uniformly in to a mono-layer on to the cold paint line in quick succession of the cold paint spraying operation. The minimum thickness is exclusive of surface applied glass beads.

The finished line shall be free from ruggedness on sides and ends and be parallel to general alignment of the carriage way.

The upper surface of the lines shall be of uniform level and free from streaks.

Preparation: The cold applied reflective road marking paint shall be stirred well to form homogeneously with the thinner recommended/supplied by the manufacturer and put into the machine with the consistency level recommended by the machine manufacturer by using proper viscometers. The thinner shall not be added more than that recommended by the manufacturer to avoid bleeding.

Properties of finished road marking:

- a. The stripe shall not be slippery when wet.

- b. The marking shall not lift from the pavement in freezing weather.
- c. After application and proper drying, the stripe shall show no appreciable deformation or discoloration under traffic and under road temperatures up to 60°C.
- d. The marking shall not deteriorate by contact with sodium chloride, calcium chloride or oil drippings from traffic.
- e. The stripe or marking shall maintain its original dimensions and position. Cold ductility of the material shall be such as to permit normal movement with the road surface without chopping or cracking.

7.3.4. Measurement

The painted markings shall be measured in sq. meters of actual area marked (excluding the gaps, if any).

In respect of markings like directional arrows and lettering, etc., the measurement shall be by numbers.

7.3.5. Payment

Pay items shall be:

Pay Item	Description	Unit
7.3.1	Hot thermoplastic road markings	Sq. m
7.3.2	Cold thermoplastic road markings	Sq. m
7.3.3	Hot thermoplastic road markings for directional arrows and lettering	No
7.3.4	Cold thermoplastic road markings for directional arrows and lettering	No

7.4 Audible and Vibratory Pavement Markings

7.4.1. Description

The work shall involve application of audible and vibratory pavement markings in accordance with the drawings or the direction of the Engineer

7.4.2. Materials

Thermoplastic: Thermoplastic material shall meet the requirements of Clause 7.1.2 of these Specifications.

Glass Spheres: Use glass spheres meeting the requirements of Clause 7.1.2. The Engineer will take random samples of glass spheres in accordance with ASTM D1214 and the Department's Sampling, Testing and Reporting Guide schedule.

Equipment

The equipment capable of providing continuous, uniform heating of the striping material to temperatures exceeding 200°C, mixing and agitating the material in the reservoir shall be used to provide a homogenous mixture without segregation. Equipment will maintain the striping material in a plastic state, in all mixing and conveying parts, including the line dispensing device until applied. Equipment shall be capable of producing a consistent pattern of transverse bars positioned at regular and predetermined intervals. It shall meet the following requirements:

- a) capable of traveling at a uniform rate of speed, both uphill and downhill, to produce a uniform application of striping material and capable of following straight lines and making normal curves in a true arc.
- b) capable of applying glass spheres to the surface of the completed stripe by automatic sphere dispensers attached to the striping machine such that the glass spheres are dispensed closely behind the installed line. The glass sphere dispensers should be equipped with an automatic cut-off control that is synchronized with the cut-off of the thermoplastic material and applies the glass spheres uniformly on the entire traffic stripe surface with 50 percent to 60 percent embedment equipped with a special kettle for uniformly heating and melting the striping material.
- c) Equipped with special kettle for uniformly heating and melting the striping material. The kettle must be equipped with an automatic temperature control device and material thermometer for positive temperature control and to prevent overheating or scorching of the thermoplastic material.
- d) Meets the requirements of the fire safety standards.

7.4.3. Application

General: Before applying traffic stripes and markings, any material that would adversely affect the bond of the traffic stripes shall be removed by a method approved by the Engineer.

Before applying traffic stripes to any Portland cement surface, a primer, sealer or surface preparation adhesive of the type recommended by the manufacturer shall be applied. Longitudinal lines should be offset by at least 50 mm from construction joints of Portland cement concrete pavement.

Traffic stripes or markings shall be applied only to dry surface, and when the ambient air and surface temperature is at least 10°C and rising for asphalt surfaces and 16°C and rising for concrete surface.

Striping shall be applied to the same tolerances in dimensions and in alignment. When applying traffic stripes and marking over existing markings, ensure that not more than 50 mm on either end and not more than 25 mm on either side of the existing line is visible.

Thickness: Base lines shall be applied having a thickness of 2 mm to 2.2 mm exclusive of the transverse audible bars, when measured above the pavement surface at the edge of the base line.

As an alternative to the flat base line, a profiled baseline meeting the following dimensions may be applied. The profiled baseline shall have a minimum height of 4 mm, when measured above the pavement surface at the edge of the inverted rib profile. The thickness in the bottom of the profile marking shall be 0.9 mm to 1.3 mm. The individual profiles shall be located transversely across the full width of the traffic stripe at approximately 25 mm. and on center, with a bottom width between 2.5 mm and 8 mm.

Dimensions of Transverse Audible Bars: The raised transverse bars shall be applied with a profile such that the leading and trailing edge are sloped at a sufficient angle to create an audible and vibratory warning,

Transverse bars on shoulder and centerline markings shall have a height of 11 mm to 14 mm, including the base line. The height shall be measured above the pavement surface at the edge of the marking, after application of drop-on glass spheres. The bars shall have an approximate length of 65 mm. The bars may have a drainage channel on each bar; the width of each drainage channel will not exceed 6.5 mm at the bottom of the channel. The longitudinal distance between bars shall be 750 mm.

Retro-reflectivity: White audible and vibratory markings shall attain an initial retro reflectance of not less than 300 mcd/1x.m² and yellow audible and vibratory markings shall attain not less than 250 mcd/1x m², respectively.

Glass spheres: Apply glass spheres to all markings. The manufacturer shall determine if a single or double application of glass spheres is used and the recommended drop rates for each application.

Protection of newly applied audible and vibratory markings

Traffic shall not be allowed onto or vehicles permitted to cross newly applied pavement markings until they are sufficiently dry. Any portion of the pavement markings damaged by passing traffic or from any other cause shall be removed and replaced.

Observation period

Pavement markings shall be subject to a 180 day observation period under normal traffic. The observation period will begin with the satisfactory completion and acceptance of the pavement marking work. The pavement markings shall show no signs of failure during the observation period. The Contractor shall replace, at his own cost, any pavement markings that do not perform satisfactorily under traffic during the 180 day observation period, shall be replaced by the Contractor at his own cost.

7.4.4. Measurement

Audible and vibratory pavement markings shall be measured in linear meter. The work shall cover all work specified in this Section, including, all cleaning and preparing of surfaces, furnishing of all materials, application, curing and protection of all items, protection of traffic, furnishing of all tools, machines and equipment, and all incidentals necessary to complete the work.

7.4.5 Payment

Audible and vibratory pavement markings shall be measured in linear meter. Payments will be full compensation for all work specified in this Section, including, all cleaning and preparing of surfaces, furnishing of all materials, application, curing and protection of all items, protection of traffic, furnishing of all tools, machines and equipment, and all incidentals necessary to complete the work. Final payment will be withheld until all deficiencies are corrected.

Pay Item	Description	Unit
7.4.1	Audible and Vibratory Pavement Markings	ln. m

7.5. Raised Pavement Markers (Road Studs)

7.5.1 General

- Raised Pavement Markers remain highly visible at night and in rainy weather.
- Micro-prismatic optics provide excellent wet and dry reflectivity
- Durable construction
- Rumble effect for added awareness

Benefits

- Durable, lightweight and impact resistant
- Provides both wet and dry reflectivity
- Easy to install and maintain
- Rumble effect for added awareness
- Nylon shanks offer excellent anchoring

7.5.2 (A) Reflective Pavement Markers (Road Studs)

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 and up to 25mm for depressible markers.

Raised pavement markers should be unidirectional on dual carriageway roads and bidirectional on undivided roads. Bidirectional markers may be used to deter wrong-way driving at critical locations.

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

Raised pavement markers should be in different colors to indicate different line marking types. Their spacing is related to speed limit, curve radius and the need to highlight the road conditions. The casing should have a neutral color such as natural metallic finish, white or black. They may have the same color of the reflector if used for unidirectional traffic.

The work cover the providing and fixing of reflective pavement marker (RPM) or road stud, a device which is bonded to or anchored within the road surface, for lane marking and delineation for night-time visibility. It reflects incident light in directions close to the direction from which it came.

7.5.2.1 Material

Plastic body of RPM/road stud shall be molded from ASA (Acrylic-Styrene-Acrylonitrile) or HIPS (Hi-impact Polystyrene) or Acrylonitrile Butadiene Styrene (ABS) or any other suitable material approved by the Engineer. The markers shall support a load of 13,635 kg tested in accordance with ASTM D4280.

Reflective panels shall consist of number of lenses containing single or dual prismatic cubes capable of providing total internal reflection of the light entering the lens face. Lenses shall be molded of methyl methacrylate conforming to ASTM D 788 or equivalent.

Design

The slope or retro-reflecting surface shall preferably be $35 \pm 5^\circ$ to base and the area of each retro-reflecting surface shall not be less than 13.0 square centimeter.

Unidirectional and bi-directional studs

Each reflector or combination of reflectors on each face of the stud shall have a Coefficient of Luminous Intensity (C.I.L.) not less than that given in **Table 7.5-1** or **Table 7.5-2** as appropriate.

Omni-directional studs

Each Omni-directional stud shall have a minimum (C.I.L.) of not less than 2 mcd/lx.

Table 7.5-1 Minimum C.I.L. Values for Category ‘A’ studs				
Entrance angle	Observation angle	C.I.L. in mcd/lx		
		White	Amber	Red
0° U 5° L & R	0.3°	220	110	44
0° U 10° L & R	0.5°	120	60	24

Table 7.5-2 Minimum C.I.L. Values for Category ‘B’ studs				
Entrance angle	Observation angle	C.I.L. in mcd/lx		
		White	Amber	Red
0° U 6° L & R	0.3°	20	10	4
0° U 10° L & R	0.5°	15	7.5	3

Note: a) The entrance angle of 0°U corresponds to the normal aspect of the reflectors when the reflecting road stud is installed in horizontal road surface.

b) The stud incorporating one or more corner cube reflectors shall be included in category ‘A’. The stud incorporating one or more bi-convex reflectors shall be included in category ‘B’.

Tests

Co-efficient of luminance intensity can be measured by procedure described in ASTM E 809 “Practice for Measuring Photometric Characteristics” or as recommended in BS: 873-Part 4: 1973.

Under test conditions, a stud shall not be considered to fail the photometric requirements if the measured C.I.L. at any one position of measurement is less than the values specified in Table 7.5-1 or Table 7.5-2 provided that

a. the value is not less than 80 percent of the specified minimum, and

b. the average of the left and right measurements for the specific angle is greater than the specified minimum.

7.5.2. (B) Solar Powered Road Markers (Solar Studs)

7.5.2.1 Material

The solar studs shall be made of Aluminum alloy and poly carbonate material which shall be absolutely weather resistance and strong enough to support a load of 13,635 kg tested in accordance with ASTM D4280. Its color may be white, red, yellow, green or blue or combination as directed by the Engineer. It should be water resistant against water ingress.

The dimensions of solar studs shall not be less than 100 mm x 100 mm x 10 mm. It shall have super bright LEDs so as to provide long visibility from a distance of more than 800 m. Its flashing rate shall not be less than 1 Hz. It should be able to give the prescribed performance in the temperature range of -40°C to +55°C. Its life shall be not less than 3 years.

Fixing of Reflective Markers Requirements

The enveloping profile of the head of the stud shall be smooth and the studs shall not present any sharp edges to traffic. The reflecting portions of the studs shall be free from crevices or ledges where dirt might accumulate. Marker height shall not be less than 10mm and shall not exceed 20 mm. and its width shall not exceed 130 mm. The base of the marker shall be flat within 1.3 mm. If the bottom of the marker is configured, the outermost faces of the configurations shall not deviate more than 1.3 mm from a flat surface. All road studs shall be legibly marked with the name, trade mark or other means of identification of the manufacturer.

7.5.3. Placement

The reflective marker shall be fixed to the road surface using the adhesives and the procedure recommended by the manufacturer. No nails shall be used to affix the marker so that they do not pose safety hazard on the roads. Regardless of the type of adhesive used, the markers shall not be fixed if the pavement is not surface dry and on new asphalt concrete surfacing until the surfacing has been opened to traffic for a period of not less than 14 hours. The portions of the highway surface, to which the marker is to be bonded by the adhesive, shall be free of dirt, curing compound, grease, oil, moisture, loose or unsound layers, paint and any other material which would adversely affect the bond of the adhesive. The adhesive shall be placed uniformly on the cleaned pavement surface or on the bottom of the of the marker in a quantity sufficient to result in complete coverage of the area of contract of the marker with no voids present and with a slight excess after the marker has been lightly pressed in place. For epoxy installations, excess adhesive around the edge of

the marker, excess adhesive on the pavement and adhesive on the exposed surfaces of the markers shall be immediately removed.

7.5.4. Warranty and durability

The Contractor shall submit a two year warranty for satisfactory field performance including stipulated retro-reflectance of the reflecting panel, to the Engineer. In addition, a two year warranty for satisfactory infield performance of the finished road marker shall also be given by the Contractor who carries out the work of fixing of reflective road markers. In case the markers are displaced, damaged, get worn out or lose their reflectivity compared to stipulated standards, the Contractor would be required to replace all such markers within 15 days of the intimation from the Engineer, at his own cost.

7.5.5. Measurement

The measurement of reflective road markers shall be in numbers of different types of markers supplied and fixed.

7.5.6 Payment

The contract unit rate for reflective road markers shall be payment in full compensation for furnishing all labor, material, tools, equipment including incidental costs necessary for carrying out the work at site conforming to the specification complete as per approved drawings or as directed by the Engineer.

Pay Item	Description	Unit
7.5.1	Raised Pavement Markers	Nos
7.5.2	Solar Powered Road Markers	Nos

7.6 Removal of old Thermoplastic Road Markings

7.6.1. Description

This work shall consist of removal of existing old road markings from the road surface before application of new thermoplastic road marking. Removal shall be done by the approved method to a satisfaction of the Engineer. Removal of old thermoplastic road markings shall be done only outside of the rescaled junction area to ensure correct guidance to road users' or to a satisfaction of the Engineer.

7.6.2. Construction Method

Old road marking shall be removed from the road surface with a milling method by milling existing lane marking, arrow etc. away from the road surface to the depth maximum 1 mm. The Engineer may approve other removal method after contractor's trial section.

Width of the milled area shall not exceed from the width of the removed marking more than 1 cm both side of the removed marking.

Inside the junction area old thermoplastic road markings shall be covered with premix bituminous resealing layer while leveling the existing junction.

7.6.3 Measurement

The measurement of removal of existing old thermoplastic marking shall be in square meter.

7.6.4 Payment

The payment shall be full compensation of all labor, equipment, material, tools, machinery and all other incidental necessary to complete the work to a satisfaction of the Engineer.

Pay items shall be:

Pay Item	Description	Unit
7.6.1	Removal of old thermoplastic road markings	Sq. m

7.7 Traffic Control and Safety Devices in Construction Zone

7.7.1. General

Traffic Control Devices in the construction zone comprise signs, delineators, traffic cones, drums, barricades, longitudinal barriers, warning tapes, flagmen, reflective jackets, headgears.

Signs: Traffic signs shall be in accordance with BRTA Traffic sign manual or as directed by the Engineer. It's material and other requirements shall be in accordance with Clause 7.1 of these Specifications.

Delineators: Delineators in constructions zone are in form of vertical posts, cones, traffic cylinders, tapes, drums etc. Vertical posts shall be in accordance with the provisions contained in BRTA Traffic sign manual or as directed by the Engineer.

7.7.2 Traffic Cones

7.7.2.1 General

Traffic cones may be of height 500 mm, 750 mm and 1000 mm, and 300 to 500 mm in diameter or in a square shape. They shall be of brilliant red/orange/yellow, ultraviolet stabilized color for maximum visibility and fade resistance under all weather conditions and ambient working temperature of -30°C to +140°C. The material shall be Linear Low Density Polyethylene (LLDP), plastic or rubber so that there is no damage to the vehicle when they are stuck. Cone and base are to be of one continuous layer to prevent tearing and base separation they should be non-crushable/flexible/tear resistant and UV stabilized and made from non-fading colors. They should return to their original shape in just 20 seconds after being crushed. The bases of cones shall be loaded with ballast (but they should not present a hazard if the cones are inadvertently struck) or anchored to check their being blown away. Their base should be designed for easy stacking without sticking. They may have retro reflective white band and mounted flashing warning light for enhanced night visibility. All traffic cones shall conform to BS: 873 (Part 8) 1985 Catalogue A and the provisional European Standard EN 13422.

7.7.2.2 Measurement

The measurement shall be for each piece.

7.7.2.3 Payment

Pay items shall be:

Pay Item No.	Description	Unit of Measurement
7.7.2.1	Traffic cones	Nos

7.7.3. Drums

7.7.3.1. General

The drums shall be of size 800 mm to 1000 mm in height and 300 mm in diameter. They shall be constructed of lightweight, flexible, and deformable materials of LLDP or plastic so that no damage is caused to the vehicle when stuck. Steel drums shall not be used. They may be of bright red, yellow or white colors. They should be portable enough to be shifted from place to place within a temporary traffic control project to accommodate changing conditions but would remain in place for a prolonged period. The markings on drums shall be horizontal, circumferential, alternative orange and white retro reflective stripes 100 to 150 mm wide. Each drum shall have a minimum of two orange and two white stripes. Any

non-retro reflective spaces between the horizontal orange and white stripes shall not exceed 50 mm wide. Drums shall have closed tops that will not allow collection of roadwork or other debris. Drums should not be filled with sand, water, or any material to an extent that would make them hazardous to motorists, pedestrians, or workers. When they are used in regions susceptible to freezing, they should have drainage holes in the bottom so that water will not accumulate and freeze, causing a hazard if struck by a motorist. Ballast shall not be placed on top of drum.

7.7.3.2. Measurement

The measurement shall be for each piece

7.7.3.3. Payment

The payment for each piece, for providing and maintenance at site shall be as per the direction of the Engineer.

Pay items shall be:

Pay Item	Description	Unit
7.7.3.1	Drums	Nos

7.7.4 Barricades

7.7.4.1. General

The barricades may be portable or permanent. Barricades may be of wooden, metal or other suitable material panels. They shall be stable under adverse weather conditions and appear significant but not to cause damage to the vehicle if they are stuck. They can be classified in 3 types, namely Type-I, Type-II and Type-III. Type-I and Type-II are portable and Type-III permanent. Because of their vulnerable position and the hazard they could create, they should be constructed of lightweight materials and should have no rigid stay bracing for A-frame designs.

7.7.4.2. Material

7.7.4.2.1. Type-I and Type II barricade: The rail/panel length shall be 2000 mm to 2500 mm for Type I and 1000 mm to 1200 mm for Type II barricade. The width of rails shall be 200 mm to 300 mm. The rails shall be painted in alternate yellow and white stripes of 150 mm width each, sloping away at an angle of 45° in the direction of traffic. The support shall be on an “A-Configuration” or otherwise at the top to permit convenient folding and staking for transportation. Their stability can be improved by ballasting. On highways or in other situations where barricades may be susceptible to overturning in the wind, sandbags should be used for ballasting. Sandbags may be placed on lower parts of the frame or stays

to provide the required ballast but shall not be placed on top of any striped rail. Barricades shall not be ballasted by heavy objects such as rocks or chunks of concrete.

7.7.4.2.2. Type-III barricade: Type-III is the permanent type and may be made of wood, metal or other suitable material. The typical configuration shall include 3 or more panels/rails, of minimum 1000 mm length (maximum length as per site requirement) and 300 mm width each, painted with alternate yellow and white stripe of 150 mm width flopping at an angle of 45°. They shall be supported and secured on 2 or more vertical supports of same material. On highways or in other situations where barricades may be susceptible to overturning in the wind, sandbags should be used for ballasting. Sandbags may be placed on lower parts of the frame or stays to provide the required ballast but shall not be placed on top of any striped rail. Barricades shall not be ballasted by heavy objects such as rocks or chunks of concrete.

7.7.4.3. Application

Type I or Type II barricades are to be used in situations where traffic is maintained through the temporary traffic control zone. They may be used singly or in groups to mark a specific condition, or they may be used in a series for channelizing traffic. Type I barricades normally would be used on conventional roads or urban streets and arterials. Type II barricades have more retro reflective area and are intended for use on highways and expressways or other high-speed roadways.

Type III barricades be used for road closure and may extend completely across a roadway or from kerb to kerb. Where provision is made for access of authorized equipment and vehicles, the responsibility should be assigned to a person to ensure proper closure at the end of each work day.

When a highway is legally closed but access must still be allowed for local traffic, the Type III barricade should not be extended completely across a roadway. A sign with the appropriate legend concerning permissible use by local traffic shall be mounted.

Signs may be erected on barricades, particularly those of the fixed type, that offer a most advantageous facility for this purpose. The ROAD CLOSED and DETOUR or ARROW signs, and the large arrow warning signs, for example, can be mounted effectively on or above the barricade that closes the roadway.

Longitudinal Safety Barriers

Longitudinal channelizing barricades are light weight channelizing devices that can be used singly as Type-I, II or III barricades, or connected so that they are highly visible and have good target value. They should be interlocked to delineate or channelize the traffic flow and mark the work zone. The inter-locking barricade wall should not have gaps that allow pedestrians or vehicles to stray from the channelizing path. Longitudinal channels

barricades are located adjacent to traffic and therefore, are subject to impact by errant vehicles. Because of their vulnerable positions, longitudinal channelizing barricades should be constructed of lightweight materials and be crash worthy. They shall be of high density polyethylene, non-fading, and high impact and U.V. resistant. They shall be of orange, white or custom colors. Their size should be minimum 1500 mm in length, 1000mm in height, and 600 mm in width. They could be filled with water through an aperture on the top and emptied by removing a plug at the base.

On roads with low speed traffic, GI sheets material could be considered for longitudinal barricades. They shall be firmly secured to vertical support system with no sharp edges to pose any hazard when struck. Their configuration shall be as per the drawing or as directed by the Engineer.

7.7.4.4 Measurement

Measurement shall be per running meter of longitudinal barrier

7.7.4.5. Payment

Payment for the running meter of complete job of providing, installation and maintenance at site as per the drawing/direction of the Engineer.

Pay items shall be:

Pay Item	Description	Unit
7.7.4.1	Barricades(Type I/II)	ln.m
7.7.4.2	Barricades(Type III)	ln. m

7.7.5. Flagman and STOP/GO Portable Boards

7.7.5.1. Materials

The flagmen or flaggers shall be deployed where:

- Workers or equipment intermittently block an unprotected traffic lane,
- One lane is used for two directions of traffic,
- It is considered necessary to guide, warn or control traffic is considered necessary.

The flagman should be alert, intelligent and capable to effectively perform the assigned duties. Flagman shall be provided with hand signaling devices such as flags and sign paddles. Flagmen must be provided with and must wear warning garments, safety headgear, footwear and gloves for their protection and for conspicuity, while flagging. Warning

garments worn at night must be of reflective material. Flags for signaling shall be minimum 450 mm by 450 mm and made of good red cloth and securely fastened to a staff of approximately of 1 m. in length.

7.7.5.2. Application

STOP/GO (Thamoon and Chaloon) Portable Sign paddles should be at least 600 mm Diameter provided with a rigid handle of minimum 1.5 m. The background Color of STOP should be red and its shape shall be octagonal conforming to BRTA Traffic Sign manual. The word STOP would be in white color. Background of SLOW sign should be green with black letters.

7.7.5.3. Measurement

The measurement shall be for each piece

7.7.5.4. Payment

Pay items shall be:

Pay Item No.	Description	Unit of Measurement
7.7..5.1	STOP/GO Portable Boards	Nos

7.7.6. Reflective Clothing

7.7.6.1. Materials

In the work zones and construction sites, all the workers, supervisors and inspecting officers shall wear high visibility fluorescent clothing with retro reflective material, so that their presence is conspicuous from a distance of 300 m. Clothing may be in form of vests, T-shirts, jackets, pants and raincoats etc., depending upon weather conditions and ease of usage. They shall be of bright colors of fluorescent red-orange or fluorescent yellow-green.

The reflective clothing's shall have reflective bands of width appropriate for the garments viz. vests, T-shirts, jackets, pants and raincoats. It shall have 360° visibility with at least one retro reflective band encircling the torso, There shall be appropriate separation distances of vertical and horizontal bands placed on torso, sleeves and trouser areas. The garment shall be free of roughness and sharp edges so as not to cause excessive irritation and the wearer should get the best possible degree of comfort and protection.

7.7.6.2. Application

The reflective clothing shall meet the requirements of standards given in EN 471:2003The material shall be tested for color and luminance, colorfastness with cracking, perspiration, laundering and UV light exposure. The material shall meet the requirements of brightness

after rainfall performance, temperature variation, abrasion resistance, flexing, cold folding and variation in temperature.

7.7.6.3. Measurement

Measurement shall be for the unite piece of clothing

7.7.6.4. Payment

Payment for providing and maintaining at site shall be as per direction of the Engineer.

Pay items shall be:

Pay Item No.	Description	Unit of Measurement
7.7.6.1	Reflective clothing	Nos

Personal Protection Equipment for Workers

All the workers, exposed to moving roadway traffic or equipment in road construction zones shall wear Reflective Material high-visibility safety vest 105 g/sqm polyester 100% (such as Flu Red/Orange or Flu Yellow /Lime 3M2925 or equivalent) and other similar apparel, helmet-headgear, steel-toe-boots, gloves, masks (such as 3M N95 and 3M 9913V or equivalent), fall-protection harness (half and full) and other protective gears for their protection.

The safety apparel shall be in accordance with Clause related to reflective clothing. The safety headgear or protective helmet shall protect the wearer against falling objects and possible serious injury. It shall address requirements of shock absorption, resistance to penetration, flame resistance, chin strap anchorages, comfortable wearing and shall meet the requirements of EN 397.

The safety shoes or boots shall provide personal protection from any possible hazard posed by the activity being done and provide comfortable wearing without giving any hindrance in the expected tasks. The work gloves shall provide protection against any personal injury that could be caused by the activities to be performed and comfort in wearing without giving any hindrance in the expected tasks. If the worker is to be exposed to dust in the work zone, he shall have respiratory protection by dust mask. Depending upon the task, workers engaged in welding operations shall have eye protection through passive welding sheet meeting the requirements of EN 175 or auto darkening sheet meeting the requirement of EN 379 / EN 169.

7.8. Conspicuity tape

7.8.1. General

Conspicuity tape is basically highly reflective, micro prismatic sheeting with pressure sensitive adhesive for easy application to trucks, trailers and large vehicles to enhance visibility and detection distance.

7.8.2. Materials

It is designed to clearly outline the side and rear perimeter of curtain and rigid sided trucks and enhance visibility and detection to up to 1,000m at night. Marking vehicles will provide enhanced safety for drivers and help to reduce accidents and save lives. This product is suitable for Buses, Caravans, emergency vehicles, Tankers, Trailers, Trucks and Inspection vehicle. It should have superior reflectivity, excellent durability and ease of application.

7.8.3. Application

Requirement

Compliant with Regulation ECE104

Adhesive Type	Pressure-sensitive, Solvent free
Applications	Buses, Caravans, Emergency & vehicles, Tankers, Trailers, Trucks
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

Constructions

Installation will be done as per Manufactures standard guidelines or as per instruction of the Engineer in charge.

7.8.4. Measurement

Measurement shall be per running meter of longitudinal barrier

7.8.5. Payment

Pay items shall be:

Pay Item	Description	Unit
7.8.1	Conspicuity tape	Ln M

7.9 Delineators

7.9.1 General

Delineators generally consist of reflectors or retro-reflective strips attached to ground-mounted posts or reflectors mounted directly onto safety barriers. Delineators are particularly beneficial for roads without road lighting and where the performance of road markings is unsatisfactory.

The work covers supplying and fixing roadway indicators, hazard markers and object markers. Roadway indicators shall be properly installed to indicate the horizontal alignment and vertical profile of the roadway so as to outline the vehicle path for safe driving.

7.9.1.1. Categories

Alignment Delineator	Highlighting road alignment and curves
Access Delineator	Demarcating accesses and intersections
Lane Delineator	Separating opposing traffic or slow traffic
Hazard Marker	Highlighting roadside hazards which cannot be reasonably removed
Diverge Gore Delineator	Highlighting diverge gores on high speed roads

Delineators are normally provided as vertical posts with an overall height shown in BRTA Traffic sign manual. They should consist of reflectors and are clearly visible at night time. The reflector should be mounted more than 0.7m above the road surface to minimize masking by plants. The appearance and color of different categories of delineators should be distinctly different and consistently applied according to their functions.

7.9.1.1.1. Alignment Delineator

Alignment delineators should be used on road sections with increased risks of an errant vehicle leaving the road such as curves, zones of narrowing or lane reduction and merging or diverging areas. The recommended color is white with a black color area surrounding the reflector. Table 7.9-1 provides a guide to the spacing of alignment delineators.

Table 7.9-1 Spacing of Alignment Delineators (ref: BRTA Traffic sign manual)

Curve Radius (m)	Spacing (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, adopt 90m where wire rope safety barriers are used

7.9.1.1.2. Access Delineator

Access delineators are provided at direct frontage accesses and intersections to highlight their presence and position. They are generally not required for major intersections where the layout is clearly defined by signs and markings.

At least one access delineator is required on each side of an access. For larger intersections, it is desirable to install two or more units to reveal the layout. A possible color scheme is white with a red color retro reflective strip wrapping around the post.

7.9.1.1.3. Hazard Markers

Hazard markers preferably have a rectangular sign face in stripes. Hazard markers are used to alert drivers of roadside hazards with the risk of frontal collisions. They should generally be positioned 0.5m to 1m ahead of hazard and may be preceded by alignment delineators guiding approach traffic to avoid the hazard.

Additionally, it could be desirable to apply reflective paints in strips of yellow and black color directly onto the hazard e.g. ending of bridge parapet or drainage structures. If the hazard presents relatively low risk, painting alone may substitute the hazard marker.

7.9.1.1.4. Lane delineators

Lane delineators are circular flexible posts installed along 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 delineator 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

7.9.1.1.5. Diverge Gore Delineator

Diverge gores are generally delineated by chevron road markings and raised pavement markers without the need for delineators. However, it could be desirable to provide delineators on the approach to serve as an additional buffer zones for diverge gores which:

- a. are located on curves
- b. have poor visibility
- c. have a high risk of collisions

Delineators for diverge gores may be of a distinct color or based on lane delineators.

7.9.2. Material

The design, materials to be used and the location of the road delineators (roadway indicators, hazard markers and object markers) shall conform to BRTA Traffic sign Manual, and to relevant drawings or as otherwise directed by the Engineer.

7.9.2.1 Post

7.9.2.1.1 Flexible guide post

A guide post which deflects when impacted by a vehicle and then returns to a vertical position, without maintenance intervention.

Furnish delineator units consisting of an approximately 3 inch (75 mm) circular hermetically sealed, acrylic plastic prismatic, reflex reflector, housed in embossed aluminium, and provided with a single grommet mounting hole or provide a flexible plastic post from the department's approved products list, complete with a 3 inch (75 mm) x 9 inch (225 mm) reflective sheet conforming to 7.1.2.5.

Obtain the engineer's approval for the type and quality of acrylic plastic reflex reflectors used.

7.9.2.1.2 Rigid guide post

Rigid guide post is a type of guide post which either fractures or remains intact and straight, but not vertical, when impacted by a vehicle.

7.9.2.1.3 Concrete Posts

The precast concrete posts shall be cylindrical shaped (150 mm dia and 1.5m long) and shall be excavated to the levels indicated on the Drawing or other parts of the Contract Documents.

7.9.2.1.4 Steel Delineator Posts

Provide a flanged channel section post weighing 1.67 kg/m per linear foot or more before zinc coating, and made of steel with the following properties:

Minimum tensile strength	50 ksi (345 MPa)
Minimum tensile yield strength	36 ksi (250 MPa)
Minimum Elongation	5.0 percent in 2 inches (50 mm)

Provide posts the length, and with mounting holes the size and spacing the plans show. Ensure the posts are symmetrical, well rolled, and free from defects that impair their strength or appearance.

Hot-dip zinc coating of the posts after completing all forming, cutting, punching or drilling. Perform zinc coating according to AASHTO M 111.

7.9.2.2 Reflector

The delineators shall be retro reflectorized as shown on the drawings or as directed by the Engineer. The reflectors on the delineators shall be of retro reflective sheeting with encapsulated lens and with the visibility of 300 m under clear weather conditions, when illuminated by the upper beam of the car headlights.

Reflectors should enable a delineator to be clearly visible 300m ahead when illuminated by a high beam light in clear conditions. They should have a size equivalent to at least 75mm or 100mm diameter and are mounted at heights in the order of 800mm to 1200mm irrespective of the mounting method.

Characteristics:

- a. Having a clear plastic base
- b. Seven square inches (4500 mm²) of reflective area, called the lens
- c. A heat sealable plastic or plastic-coated metallic foil back, fused to the lens under heat and pressure around its perimeter and the central mounting hole to form a unit sealed against dust, water, and vapor
- d. For reflector color, use the color as per direction of Engineer in charge.

Provide a lens with a smooth front surface; free from protrusions or indentations, other than a central mounting hole and identification, with a prismatic pattern on the rear surface that result in total internal reflection of light. Ensure that the manufacturer's trademark is molded legibly in the lens face.

7.9.2.2.1. Barrier mounted Reflectors (Double Sided)

Reflectors consisting of top retro reflective unit exposed area of 125 cm² white color & bottom retro reflective unit exposed area of 35 cm² red color wide angle cube corner micro prismatic nonmetallic retro reflective sheeting conforming to the retro reflection values as per ASTM D 4956-16b Type XI table specification. The tubular delineator shall have a core and shell construction, shell shall be made of tough, high impact resistant, injection-molded, thermoplastic outer body & the inner core shall consist of powder coated or painted Mild steel of minimum thickness 1.0mm on which retro reflective sheeting is pasted on one side such that at least 60% of exposed area is a flat surface & core-shell structure shall be of height not less than 800 mm above the ground and width not less than 80 mm. The metallic core of the delineator shall extend 300mm beyond the shell length from bottom for installing in the ground.

7.9.2.2.2 Delineator Brackets

Provide either structural steel or aluminum brackets (conform to ASTM B 221), for mounting delineators on concrete barriers or other structures.

7.9.2.2.3. AFP (Aluminum flexible prismatic) Sheeting

AFP Sheeting flexible prismatic sheeting shall be of 0.9 m width and laminated at the back with a 50-micron thick Aluminum (Al) foil with pressure sensitive adhesive and liner, further this flexible prismatic sheeting shall have screen printed arrow /slant line pattern in black Color on top in continuous roll format. Neither AFP sheeting nor the flexible prismatic sheeting used shall crack when slowly bent in second time around a 1/8th inch mandrel after being conditioned for 24 hrs. at 0 degrees and tested as per section S2.2.2 of ASTM, D 4956-16b. The AFP sheeting with the liner removed shall be applied with a neoprene contact adhesive with polychloroprene as base viscosity of 200-450 cps and solid content of 20-30 % once applied the edges of the product shall be extremely resistant to peel off.

7.9.3 Construction and Installation

7.9.3.1. Erecting Delineator Posts and Brackets

- a. Erect steel or flexible plastic posts to support delineators or small signs
- b. Provide zinc coated steel or aluminum angles or brackets to support delineators mounted on concrete barriers or other structures
- c. Set the posts and steel or aluminum brackets for the delineators at the locations and offsets the plans show or the engineer directs
- d. Erect the posts to a true vertical position by driving with equipment that does not damage the post. The contractor shall remove and replace all posts bent or damaged otherwise by own operations at no expense to the department. Drive the posts into the ground according to plan details, unless specified otherwise
- e. Mount delineator brackets with stainless steel bolts, anchors, and gaskets if required, according to plan details
- f. The curved side of the post is to face in the direction of travel on the roadway

7.9.3.2. Installing Delineators

- a. Erect reflector units on steel or wood marker posts, or on structures
- b. Assemble the delineators in the field, for mounting according to the plans requirements, as single delineators or double delineators
- c. Mount the center of the top delineator unit at the height the plans show
- d. Attach each delineator unit securely to the supporting steel post. If placing on structures, mount according to plan details
- e. If required, attach delineator units to marker posts with aluminum screw-nails according to plan details

- f. Notch the marker post to accept the delineator unit or units, and drill or saw the base of the post if required, all as the plans show.

7.9.3.3. Temporary Delineators

Provide, install, and remove temporary delineators and temporary delineator posts.

7.9.4. Warranty

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.

7.9.5. Measurement

The measurement shall be for each piece of Post

7.9.6. Payment

Delineator Posts and Delineator Brackets

- (a) The department will measure Delineator Posts Steel, Concrete, Delineator Posts Flexible, and Delineator Brackets by each individual post or bracket acceptably completed.

Delineators and Temporary Delineators

- (a) The department will measure Delineators and Temporary Delineators by each individual reflector acceptably completed.

The department will pay for measured quantities at the contract unit price under the following bid items:

Pay Item No.	Description	Unit
7.9.1	Delineator Posts Steel	Nos
7.9.2	Delineator Posts Flexible	Nos
7.9.3	Concrete posts	Nos

7.10 Rumble Strip Median

7.10.1. Description

The item shall consist of providing rumble strip median to carriageway for separating traffic flow. Rumble strip median shall be constructed by implementing longitudinal strips both side of the road's middle line and connect strips with transverse diagonal to each other as shown in the drawings or instructed by the Engineer.

7.10.2. Materials

Liquid asphalt for tack coat shall be rapid-curing type cutback grades RC-2 or RC-4 or as directed by the Engineer, and shall conform to the requirements of sub-clause 3.7.3 of this specification. Bituminous tack coat shall be applied on the surfaces where rumble strips / raised pedestrian crossing will be constructed.

The bituminous mixture for rumble Strips Median shall conform to the requirements for clause 4.5 premix bituminous carpeting of this specification.

3% of cement shall be used in bituminous mixture as filler to improve the strength of completed Rumble Strips Median.

Steel forms shall be used for construction of Rumble Strips Median. Forms shall be placed on the road surface tightly so that shape of the works is obtained as per drawings.

7.10.3. Construction Method

7.10.3.1. Surface preparation

Contractor shall mark the middle line of the road section to ensure correct alignment of rumble strip median and measure and mark the location of longitudinal strips as shown in the drawings.

Immediately prior to the application of the tack coat, the bituminous surface shall be cleaned free of all dirt, dust, and other foreign substances which, would prevent proper bonding of the tack coat.

7.10.3.2. Application of Tack 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 tack coat shall be sprayed with approved mechanical or 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 exceed one-quarter ($1/4$) liter per square meter. The tack coat shall be applied uniformly and to the satisfaction of the Engineer.

7.10.3.3. Placing of Bituminous Mixture

Contractor shall prepare steel forms with the correct dimension for the construction of rumble strip median as shown in the drawing. As soon as the tack coat has settled, hot bituminous mixture (according to the sub-clause 4.5) shall be placed and consolidated in to the form by approved working method. After the mixture is settled, the form shall be removed.

To complete rumble strip median **rain** transverse diagonal strips to 45°degree angle after every 2.0 meter shall be constructed to connect longitudinal strips together as per drawings. During the construction of rumble strip median rain water gap in transverse direction must be included in every 2.0m interval with 50 mm gap width. Dimension of rain water gap must follow the contract drawing or as per direction of Engineer.

7.10.3.4. Compactions of Bituminous Mixture

Compaction shall be done with approved method by the Engineer to ensure correct alignment, shape and height of the longitudinal strips as shown in the drawing. Height and alignment must be rechecked after the compaction. Before thermoplastic marking is applied, all strips must be cleaned from dirt and dust to ensure bonding of marking.

7.10.4 Measurement

Rumble strips median constructed by premix bituminous carpeting materials with seal coat at the same time will be measured in linear meter actually constructed and accepted in conformity with size and details as shown on drawings or as directed by the Engineer.

Bituminous tack coat shall be measured separately as stated under the item 3.7.1 of these specifications.

Thermoplastic road marking on the top of rumble strip median shall be measured in the unit of square meter as described under the item 7.3.4.

Rumble strips median constructed by premix bituminous carpeting materials with seal coat measured above shall be paid for at contract unit rate linear meter, which shall be payable in full compensation for furnishing all labor, carriage, material, tools, equipment and all other incidental necessary to complete the work.

7.10.5 Payment

Thermoplastic road marking on the top of the rumble strip median shall be paid at the contract unit rate of square meters and it shall be paid under the pay item 7.3.1 or 7.3.2

Bituminous tack coat shall be paid separately under the pay item 3.7.1.

Pay item	Description	Unit
7.10.1	Rumble Strips Median	Lin.m
3.7.1	Bituminous Tack Coat	Sq. m
7.3.1	Hot thermoplastic road markings	Sq. m

7.3.2	Cold thermoplastic road markings	Sq. m

7.11 Solid concrete Interlocking Paving Blocks Pavement on footpath

7.11.1. Description

This work shall consist of furnishing all materials, like interlocking paving blocks for construction of footpath surface, including sand laying course under the block for installation.

7.11.2. Material requirements

7.11.2. 1 Cementitious Materials

Cementitious Materials shall conform to the following applicable ASTM specifications

- a. Portland cements - Specification C 150
- b. Blended cements - Specification C595/C 595. Types IS or IP
- c. Silica fume - Specification C 1240

7.11.2.2. Aggregates

Aggregates shall conform to the ASTM C-33

- a. Normal Weight - Specification C33
- b. Lightweight - Specification C331

7.11.2.3. Chemical admixtures

Chemical admixtures shall conform to the following applicable ASTM specifications.

- a. Air-entraining admixtures - Specification C 260
- b. Water reducing, retarding and accelerating admixtures - Specification C 494
- c. Pigments for integrally Colored concrete - Specification - C979

7.11.2.4. Physical Requirements

- a. Units shall be of specified or approved shape, size and thickness, capable of being fitted and placed with one hand, and shall have an exposed face area less than or equal to 0.065 m^2 (100.75 in^2), and their aspect ratio (that is, overall length divided by thickness) shall be <4 . The minimum thickness shall be 60 mm (2.375 in).
- b. Concrete units covered by this specification may be made from lightweight or normal weight aggregates or mixed lightweight and normal weight aggregates.

- c. Compressive strength - at the time of delivery to the work site, the average compressive strength of the test samples shall be not less than 49N/mm^2
- d. Cement component of the compacted concrete shall not be less than 380 kg/m^3
- e. Absorption - The maximum average absorption of the test samples shall not be greater than 5% with no individual unit greater than 7%.
- f. Resistance to freezing and thawing - If directed by the Engineer, the Contractor shall strictly satisfy the Engineer either by proven field performance or a laboratory freezing-and-thawing test that the paving units gave adequate resistance to freezing and thawing. If a laboratory test is used, when tested in accordance with test methods C67, specifications shall have no breakage and not greater than 1.0% loss in dry mass of any individual unit when subjected to 50 cycles of freezing and thawing. This Test Method shall be conducted not more than 12 months prior to delivery of units.
- g. Abrasion Resistance - when tested in accordance with Test Methods C 418, specimens shall not have a greater volume loss than $15\text{ cm}^3 / 50\text{ cm}^2$ ($0.195\text{ in}^3 / 7.75\text{ in}^2$) The average thickness loss shall not exceed 3 mm (0.118in)
- h. Dimensional Tolerance - Length or width of units shall not differ by more than +1.6 mm (+1/16in) from approved samples. Heights of units shall not differ more than $\pm 3.2\text{ mm}$ ($\pm 1/8\text{ in}$) the specified standard dimension.

7.11.2.5. Spacer Nibs and Chamfers

- a. A projection on vertical face of unit intended as an aid to laying should be provided in the Interlocking Paving Units.
- b. A chamfer around the wearing surface shall be desirable and the work size of the width and depth of any chamfer shall have to be prior approved by the Engineer.

7.11.2.6. Manufacturing / Casting

The solid concrete Interlocking paving Unit/Blocks shall be factory made "Pressed" type of approved quality, uniform texture and color, manufactured by employing a pressure not less than 5 NM/m^2 over the entire surfaces receiving the pressure.

7.11.2.7. Tolerances

The maximum dimensional deviations from the stated work sizes for the paving blocks measured shall be as follows:

Length = $\pm 2\text{ mm}$

Width = $\pm 2\text{ mm}$

Thickness = $\pm 0\text{ mm}$

7.11.2.8 Sampling and Testing

- a. The Engineer/Engineer's representative shall be accorded proper facilities to inspect and sample the units at the place of manufacture from the lots ready for delivery
- b. Sample and testing shall be in accordance with Test Methods C140. except as required in 4.5 Units tested in compression shall be whole. If the testing, machine does not have sufficient force to break a whole unit, then the unit shall be cut in half along the shortest axis and one half tested. Units with protruding, smaller ends shall have the ends saw cut and the remaining larger pieces tested. This specimen shall be symmetrical about two axes.

7.11.2.9 Visual Inspection

All units shall be sound and free of defects that would not interfere with the proper placing of the units or impair the strength or performance of the construction.

7.11.3. Construction Method

There are three layers in an Interlocking block paving:

- a. Improved Sub-grade: Laid as for a conventional road, the thickness of improved sub-grade will be minimum 20 cm and other requirement will fulfill the specification of clause no. 3.8
- b. The laying course - a layer of carefully screeded compacted minimum thickness 5 cm of "Sylhet" coarse sand of Fineness Modulus ≥ 1.8
- c. The surface course - the interlocking paving blocks themselves of approved size, shape, Color, texture and finish.

In additional edge restraint is essential to prevent the blocks from moving sideways and becoming loose.

It is normally provided by standard pre-cast concrete kerbs.

7.11.3.1 Basic Paving operations

- (a) Place and screed the laying course
- (b) Place the blocks
- (c) Complete the edges
- (d) Vibrate the surface

7.11.3.2 Edge Restraint

- a. This is normally provided by pre-cast kerbs which are laid prior to paving.
- b. It is essential that the kerb foundation should not project in front of the kerb as the surplus concrete will prevent blocks from being laid properly. Similar care must be taken with the hunching to gully and manhole surrounds.
- c. Edge restraint is still need even where special edge blocks are used.

7.11.3.3 Laying course

The laying course, about 50 mm thick after vibration consists of washed sharp "Sylhet" sand containing not more than 3% of silt and clay by weight and with not more than 15% retained on a 2.3.6 mm sieve. To achieve the best regularity in the finished road surface, the sand should be uniform in type and moisture content, spread to a smooth level without uneven pre-compaction.

To help maintain uniformity, the sand should be obtained from a single source, allowed to drain before use and sheeted over to minimize moisture changes.

7.11.3.4 Screeding to Level

Screeding is done by traditional methods. On roads & footways of up to 5m wide, screeding can be done from the kerbs. For wider roads, or over large areas, temporary screed rails set to level can be used.

It is essential to take care with screeding, not only because it gives a better footpath surface but also because it help as the block layer.

A cambered screed board is needed for roads or footways with a cambered cross-section.

7.11.3.5 Surcharge

After final vibration, the blocks will be lower than their initial level because the laying coarse sand has been compacted and some has moved up into the joints between the blocks. Thus the sand has to be laid to a surcharge, the amount of which depends on the type and moisture content of the sand but is normally in the range of 5 to 15 mm. For ensuring that the surcharge is correct, the final road level should be checked after completion of the first few meters and then at frequent intervals. After checking if it is found that the final level is incorrect, the blocks may be lifted and stacked and the sand thoroughly raked and rescreeded at a new level.

7.11.3.6 Surface course

The positioning of the initial blocks demands extra care. To give the required laying pattern the blocks must be placed at the correct angle against after starting edge such as a row of concrete channel blocks.

Each block has to be placed very carefully so as not to disturb its neighbors and it is not until three or four rows have been placed that the normal rapid laying rate can be achieved. However, with a herringbone pattern where the blocks are at 90° to the centerline half blocks should be fitted at the starting line.

7.11.3.7 Laying

Each block must be placed firmly against its neighbors, being held slightly above the laying course so as not to disturb the sand until the block is in its correct place. Any damaged blocks should be rejected.

All blocks must be laid so that they fit closely together. If joints begin to open, the blocks should be knocked together with a hide mallet. Care must be taken not to till the blocks on the leading edge of the laying face by standing or kneeling on them.

Block-laying is continued until enough area has been laid to make vibration worthwhile - say, 15 to 20 square meters. Men or light equipment can move over the blocks before they have been vibrated. This may cause an uneven surface which may be 'Ironed out by the plate vibrator.

7.11.3.8 Compaction of road bed/paving blocks with plate vibrator

Plate vibrator shall be used for compacting road bed just before the placement of paving blocks. Plate vibrator shall also be used to get the paving blocks initially set. A plate vibrator shall have the plate area between 0.2 and 0.3 square meters and a centrifugal force of approximately 1.0 tonne.

7.11.3.9 Edging

Where blocks do not fit at the edges the spaces are filled with cut blocks, Cutting machines are available to split blocks, but very small pieces are best chipped off with a bolster and hammer.

Where the gaps are small, with a dimension less than 40mm, they can be filled with a 4:1 sand mortar.

7.11.3.10 Filling the Joints

After the initial vibration, sand as per following grading is brushed over the surface of the blocks, and is vibrated into the joints by a further two or three passes of the Plate vibrator. After all the joints are filled, surplus sand can be swept away.

Table 7.11-1 for Joint Filling Sand Grading

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

7.11.4. Measurement

The unit of measurement shall be in square meters of footpath covered by solid concrete Interlocking Paving Blocks of specified thickness.

7.11.5 Payment

The payment shall be the full compensation for the cost of factory made interlocking paving units, labor, laying course, cement sand mortar as mentioned above, transportation and cost of all materials, tools and plants, compaction costs and all other incidental costs necessary to complete the work.

Pay Items No.	Description	Unit
7.11.1	Procurement and construction of footpath with 60 mm thick solid concrete interlocking Paving Blocks including 5 cm compacted coarse sand laying course.	Sq. meter

7.12 Pre-cast Kerbs for Median/ NMT Lane Separator/ Roundabout/ Footpath

7.12.1 Description

The work shall consist of construction of median / NMT lane separator / roundabout / footpath with pre-cast factory made ‘Pressed’ kerbs, including end protection of median or NMT lane separator as shown in the drawings or instructed by the Engineer, in conformity with lines, levels, typical cross sections and locations shown in engineering drawings and these technical Specifications or as instructed by the Engineer.

7.12.2 Materials

7.12.2.1 Cementitious Materials

Cementitious Materials shall conform to the following applicable ASTM specifications

- Portland cement – Specification C 150
- Blended Cements – Specification C595/C 595 M. Type IS or IP.
- Silica Fume – Specification C 1240

7.12.2.2 Aggregates

Aggregates shall conform to the ASTM C-33

- Normal Weight – Specification C 33
- Lightweight – Specification C 331

7.12.2.3 Chemical Admixtures

Chemical Admixtures shall conform to the following applicable ASTM specifications

- Air-entraining Admixtures – Specification C 260
- Water reducing retarding and acceleration admixture – Specification C 494

- c. Pigments for integrally Colored concrete specification C979

7.12.2.4 Steel Reinforcement –

Steel reinforcement must follow ASTM A615 or ASTM A617M or ASTM A706M as specified in drawings or as directed by the Engineer.

7.12.2.5 Physical Requirements

- a. The pre-cast kerbs shall be of specified or approved shape, size and thickness – factory manufactured with approved materials in accordance with the specifications and in conformity with lines, level and typical sectional details as shown on drawings or as directed by the Engineer.
- b. Concrete units covered by this specification may be made from light weight or normal weight aggregates or mixed lightweight and normal weight aggregates.
- c. Compressive strength – at the time of delivery to the work site, the average compressive strength of the test samples shall be not less than 30N/mm^2 with no individual unit less than 25.8 N/mm^2
- d. Cement component of the compacted concrete shall not be less than 350 Kg/m^3
- e. Absorption – The maximum average absorption of the test samples shall not be greater than 3.2% with no individual unit greater than 5% when tested within one months after manufacture and between 2.8 to 2.4% when tested after two months of its manufacturing.
- f. Resistance to freezing and thawing – If directed by the Engineer, the contractor shall strictly satisfy the Engineer either by proven field performance or a laboratory freezing and thawing test that the kerbs and edging have adequate resistance to freezing and thawing. If a laboratory test is used, when tested in accordance with test methods C67, specimens shall have no breakage and not greater than 1.0% loss in dry mass of any individual unit when subjected to 50 cycles of freezing and thawing. This test method shall be conducted not more than 12 months prior to delivery of kerbs
- g. Dimensional Tolerance – All kerbs, shall be manufactured according to the profiles shown on drawings and in typical sectional details. When sampled at random and measured for length, width or height, the average dimensions of the twelve values obtained from the four measurements on each of the three units sampled shall be within $\pm 4\text{mm}$ of the specified dimensions but none of the original values shall vary from the average by more than $\pm 2\text{mm}$.
- h. Angles and Arises – All angles of the products, with the exception of angles resulting from the splayed or chamfered face shall be right angles, subject to the tolerances as stated sub-clause 4.6
- i. The Arise shall be clean and with the exception of the rounded arises, sharp. The wearing surfaces shall be true and out of winding, subject to the tolerances in above sub-clause.

7.12.2.6 Manufacturing/Casting

All solid concrete kerbs shall be factory made “Pressed” type of approved quality, uniform texture and color, manufactured by employing a pressure not less than 5 MN/m² over the entire 4 surfaces receiving the pressure.

7.12.2.7 Finish and Color

Surface Finishes – Unless specified otherwise, all surfaces which are exposed in service shall be clean. Free from dents, bulges, depressions and completely smooth of uniform natural color, texture and free from any marks or stains.

7.12.2.8 Testing

Contractor must supply latest test results from manufacturer or he must arrange new tests to satisfy these requirements. Result should not be older than 3 months. It shall be the responsibility of the contractor to arrange testing equipment and instrumentation and carry out the periodic testing of the products in accordance with Engineer’s directions.

7.12.3 Construction Methods

7.12.3.1 Construction of median / NMT lane separator / roundabout / footpath

The median / NMT Lane separator / Roundabout shall be constructed as per drawing. The median/NMT Lane separator / roundabout shall be constructed on the existing carriageway and requires excavating existing pavement as shown on the drawing. All joint and concrete work shall be cured properly for a minimum period of 7 (seven) days.

7.12.3.2. Installation of Pre-cast Kerbs

- a. Only good quality kerbs is allowed to use for median / NMT lane separator / roundabout / footpath
- b. The pre-cast units shall be fixed or placed in position as per the details indicated in typical sectional details.
- c. The bedding concrete shall be class – 15 with stone aggregates as per the Technical Specifications and the vertical mortar joints shall be in cement sand mortar (at 1:3 proportion) finished with regular recessed pointing as per approved sample or direction of Engineer.
- d. All pre-cast concrete units to be fixed in concrete shall be presoaked and moist to the satisfaction of the Engineer, before placing the same over bedding concrete or before placing cement sand mortar (1:3) in joints. All concrete work and joints shall be cured for a period not less than 10 days.

7.12.4 Measurement

Kerb shall be measured in linear meters actually constructed and accepted in conformity with size and shape as shown on drawing or as directed by the Engineer. The length shall be measured at center line of top of finished surface. Payment for the installation of pre-cast Kerbstone shall be paid at the contract unit price per linear meter under the pay item 7.12.2 (Type K2, dimensions xxx) or under the pay item 7.12.3 (Type K3, dimensions xxx). Backfilling shall be measured and paid separately under clause 7.13.

7.12.5 Payment

Kerb as measured above, shall be paid for at the contract unit rates in linear meter, which shall be payment in full compensation for furnishing all labor, carriage, material, tools, equipment, excavation, cutting pavement, provisions of side offset kerb detail, vehicular access drop kerb arrangement, together with bed, haunch, fixing concrete, construction of end protection to median or NMT lane separator and all other incidentals necessary to complete the work to the satisfaction of the Engineer.

Pay Item No.	Description	Unit of Measurement
7.12.1	Procurement and installation of pre-cast kerb Type “K1” for median, NMT lane separator and roundabout	Lin. m
7.12.2	Procurement and installation of pre-cast kerb Type “K2” for footpath	Lin. m
7.12.3	Procurement and installation of pre-cast Kerb Type “K3” for footpath	Lin. m

7.13 Backfilling of Median/NMT Lane Separator/Roundabout

7.13.1 Description

The item shall consist of backfilling of constructed median/NMT lane separator /roundabout as shown in the drawings or instructed by the Engineer.

7.13.2 Materials

Earth free from roots, stones and other bigger particles, which may cause severe injuries in case of vehicle hit to a Median/NMT Lane separator/roundabout, shall be used for backfilling.

7.13.3 Construction

Earth filling of median/ Lane divider/ Roundabout

The space in the medians/NMT Lane separator / roundabout constructed shall be filled with earth. The placing of earth shall be carried out in successive layers for the full width of fill as shown on the drawings and in such lengths as are suited to the watering and compaction methods utilized. The layer shall not exceed 150 mm in thickness on completion. Earth should be free from roots, soda or other deleterious and foreign materials.

7.13.4 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.

7.13.5 Payment

Backfilling of median / NMT lane separator / roundabout with earth shall be paid for at the contract unit rate cubic meters. Payment shall be the full compensation of 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 cubic meters. The payment shall be full compensation to completion of work.

Pay Item	Description	Unit Measurement
7.13.1	Earth filling in the road median / NMT lane separator / roundabout	Cubic Meters
7.13.2	Roadway Excavation and the removal of existing flexible pavement structure.	Cubic Meters

7.14 Dismantling Damaged Kerb Stones and Re-use of Kerb Stones

7.14.1 Description

The work shall consist of furnishing all necessary tools, equipment and materials for dismantling of damaged kerbstones or cleaning and recovering kerbstones in accurate condition for reusing in construction work.

7.14.2 Construction

The existing kerb stones shall be recovered from the kerbstones area being dismantled mechanically or manually and during dismantling care shall be taken so that considerable numbers of kerb stones are saved. After necessary cleaning, these kerbstones shall be installed to the same locations or to other location as per drawings.

The joints of kerb stone shall filled with cement mortar in the proportion of 1 parts of cement to 4 parts of sand. Curing by water to these works shall be done for at least 7 days.

7.14.3 Measurement

The completed work of dismantling and reinstallation of kerbstones shall be measured in linear meter along the center line of the kerbstones line. The measurement shall be recorded before dismantling and after installing separately. If all the kerbstones are not used in the new work the surplus dismantling kerbstones shall be stocked piled and handed over to RHD.

7.14.4 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, equipments and incidentals necessary for the proper completion of work as specified in the contract documents or as directed by the Engineer.

Pay item shall be:

Pay Item	Description	Unit
7.14.1	Dismantling of existing kerbstones	Lin. m
7.14.2	Reinstallation of kerbstones	Lin. m

7.15 Painting of Median/NMT Lane Separator/Roundabout

7.15.1 Description

This shall consist of furnishing all necessary tools, materials, labor etc. for painting road median / NMT lane separator / roundabout with reflective as shown in the drawings or instructed by the Engineer.

7.15.2 Materials

The primer coat of plastron sealer or an approved equivalent material of known paint manufacturer shall be used on concrete surface or plastered brick surface.

Reflective paint shall be of high intensity grade and as approved by the Engineer.

7.15.3 Method of Application of Paint

Reflective paint shall be used as recommended by manufacturer. First primer shall be used on the surface after necessary cleaning is completed. Then 1st and 2nd coats of painting shall be applied as per recommendation of the manufacturer. Two coats of reflective paint with one prime coat of plastron sealer shall be applied on the specified surface. At best after one day, the 2nd coat shall be applied. The application of paint may be by brush/spray or roller as per convenience of the work.

Reflective painting of alternate black and white color shall be applied on face of the road medians / NMT lane separator / roundabout as shown in the drawings or instructed by the Engineer.

7.15.4 Measurement

The reflective painting of median / NMT lane separator / roundabout shall be measured in square meters of the painted area completed and accepted by the Engineer.

7.15.5 Payment

The quantities as measured above shall be paid for at the contract unit prices per square meter. The payment shall be full compensation for material, equipment, tools and incidental necessary to complete the work.

Pay item shall be:

Pay Item No.	Description	Unit Measurement
7.15.1	Reflective painting of road medians / NMT lane separator / roundabout	Sq. m

7.16 Demolition and Removal of Existing Median

7.16.1 Description

This item shall include demolition of different type of road medians, like kerbstone median, concrete median or New-Jersey Barrier as shown in the drawings or as directed by the Engineer and removal of demolished material from the site.

Item includes also removal of existing filling material either to disposal site or temporary stock pile for reuse as instructed by the Engineer.

7.16.2 Method

The demolition of existing road medians shall be done as per approved method or as instructed by the Engineer. The contractor must submit demolition method to Engineer for approval one week before commencing the work.

Only required sections shall be demolished and remaining part of median must remain undisturbed.

Safety Precautions

The contractor shall comply with all safety measure while demolishing the medians against traffic flow on the road.

7.16.3 Measurement

Demolition and removal of existing road medians shall be measured in linear meter actually demolished and accepted.

7.16.4 Payment

Quantities measured as stated above shall be paid at the contract unit price per linear meter. The payment shall be full compensation for furnishing all required tools, machines, labor, materials, removal of demolished median and filling material for disposal or stock pile and incidentals for completion the work.

Pay Item No.	Description	Unit
7.16.1	Demolition and removal of existing median (including filling material)	Linear Meter

7.17 Crash Barriers

7.17.1 General

The work shall consist of construction, provision and installation of crash barriers as shown in the drawing or as directed by the Engineer. The crash barrier is provided to absorb the impact energy and reduce the severity of accidents involving vehicles leaving the traveled way. It should be installed where the severity of accidents due to striking the barrier, which is shielding the hazard, is lower than what it will be without the barrier.

The crash barriers can be classified as flexible, semi-rigid, or rigid. The flexible system is the most yielding type, which may be composed of wire rope fencing. Semi-rigid barriers offer requisite resistance to control the deflection of longitudinal member to an acceptable limit; metal beam crash barriers give this system. Rigid system does not deflect on impact but causes the maximum severity of impact; concrete crash barrier is the rigid system.

They are generally longitudinal roadside crash barriers and median barriers. Some of the commonly encountered roadside obstacles are bridge piers, abutments and railing ends, roadside rock mass, culverts, pipes and headwalls, cut slopes, retaining walls, lighting supports, traffic sign and signal supports, trees, and utility poles. Median barriers are provided to check head-on-collisions, especially on highways with narrow medians, caused by out-of-control vehicles jumping across the medians.

Raised curbs or drains should not be provided between the traveled way and the barriers. These destabilize the vehicle balance and disturb its equilibrium before it strikes the barrier, thus defeating the essential purpose of safety and redirection of the impacting vehicle.

Categories:

Category	Application	Containment for
P-1: Normal Containment	Bridges carrying expressway, or equivalent	15 kN vehicle at 110 km/h, and 20 degree angle of impact
P-2: Low Containment	All other bridges except bridge over railways	15 kN vehicle at 80 km/h, and 20 degree angle of impact
P-3: High Containment	At hazardous and high risk locations, over busy railway lines, complex interchanges, etc.	30 kN vehicle at 60 km/h, and 20 degree angle of impact

7.17.2. Placement

Placement recommendations determine the exact layout of the barrier and should be made by the design engineer keeping in view the lateral offset of the barrier and flare rate. The final layout shall be a site specific combination of these factors. The barriers should be as far away from the traffic as possible and should preferably have uniform clearance between the traffic and the hazard.

As far as possible the safety barrier should be placed beyond 2.5 m of the traveled way. For long and continuous stretches, this offset is not critical. The distance between the barrier and the hazard should not be less than the deflection of the barrier by an impact of a full sized vehicle. In case of embankments, a minimum distance of 60 cm should be maintained between the barrier and the start of embankment slope or a hazard to prevent the wheels from dropping over the edge.

Flatter flare rates may be used particularly where extensive grading would be required to ensure a flat approach from the traveled way subject to the availability of right of way.

At locations, where the two adjacent carriage ways are at the same level, the barrier shall be placed in the center of the median, duly taking into consideration, the drainage requirements. The placement of median barriers in cases where the two carriageways are at different levels is a function of the slopes between the two medians.

Crash barriers should be provided with reflectors to enhance their visibility in the night time.

Warrants

The crash barriers shall be provided at following locations.

- a. Where the height of embankment is 3m or more,
- b. Where the embankment is retained by retaining structure,
- c. Where the median is depressed, flushed or having the width of less than 4.5 m. The barriers shall be for both directions of travel,
- d. On valley side of highway in mountainous and steep terrain,
- e. Between the main carriageway and footpath on bridges,
- f. At hazardous locations, as per the direction of the Engineer.
- g. On the highways with ADT more than 20,000 PCUs and with medians width less than 9m, median barriers are required. The probability of a vehicle crossing across the median is relatively low and median barriers in such cases are optional.
- h. Median barriers to shield fixed objects in 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.
- i. Any hazardous location as directed by the Engineer.
Medians with width between 9 and 15 m do not warrant a barrier unless there is an adverse history of median crossovers. Median barriers may be impractical where a road has a large number of closely spaced median openings since the barrier needs to be terminated with an end treatment at these points. An evaluation of the number of median openings, accident history, alignment, sight distance, design speed, traffic volume and median width requires to be made prior to taking a decision on installation of a median barrier.

7.17.3. Materials

The concrete barriers shall be constructed either by the “cast-in-place with fixed forms” method or the “extrusion or slip form” method or a combination thereof at the Contractor’s option with the approval of the Engineer. Where “extrusion or slip form” method is adopted full details of the method and literature shall be furnished.

Concrete barriers shall be constructed with M 20 grade concrete or as indicated in the drawing and with thermo mechanically treated (TMT) deformed bars of grade S415

An expansion joint with pre-molded asphalt filler board shall be provided at the junctions of crash barrier on structure and crash barrier on the fill. The crash barrier on the fill shall

be constructed in pieces of length not exceeding 20 m, with pre-molded asphalt filler board joints.

7.17.3.1 Concrete Crash Barrier/New Jersey Barrier

7.17.3.1.1 Construction operations

The location of crash barrier shall be strictly adhered to as shown on the drawing and/or as directed by the Engineer. Concrete crash barriers shall present a smooth, uniform appearance in their final position, conforming to the horizontal and vertical lines shown on the plans or as ordered by the Engineer and shall be free of lumps, sags or other irregularities. The top and exposed faces of the barriers shall conform to the specified tolerances.

Based on evaluation of vehicle direction, sight distance, structural stability and the psychological effect of barrier height on driver reaction, the most desirable height of the median barrier is 80 cm. 'New Jersey' type is the most common shape of concrete crash barrier. Variations up to 50 mm in height of barrier can be made in the total height of the barrier to meet the site requirements. It is however important to maintain the height of lower slope between 20 cm and 35 cm so as to reduce the chances of overturning of the vehicles.

The concrete barrier may be precast in lengths up to 6 m depending upon the feasibility of transport and lifting arrangements. The minimum thickness of foundation may be 25 mm thick cement concrete or hot mix asphalt placed at the base of barrier to provide lateral restraint. Where more than 75 mm thick overlay on the road pavement is anticipated, the foundation step may be increased to 125 mm. However, longitudinal roadside concrete barrier should have elaborate footing design which is structurally safe unless sufficient earth support is available. Backfilling to the concrete barriers shall be compacted in layers to the compaction of the surrounding earthwork.

Tolerance: The overall horizontal alignment of rails shall not depart from the road alignment by more than + 30 mm, nor deviate in any two successive lengths from straight by more than 6mm and the faces shall not vary more than 12 mm from the edge of a 3 m straight edge. Barriers shall be at the specified height as shown in the plans above the edge of the nearest adjacent carriageway or shoulder, within a tolerance of + 30 mm.

End Treatment, Paint and One - way/ Two-Way Reflectors: The road side concrete barrier shall be provided with an end treatment by tapering the height of terminating end within a length of 8 m to 9 m. Median crash barrier shall be terminated sufficiently away from the median opening. It shall be provided with an end treatment, which shall be obtained by tapering the height of terminating end of the median barrier within a length of 8 m to 9 m.

Barriers should be painted Yellow/Black as per the approved pattern. One - way/ Two-Way Reflectors (Red/White on edge-barriers and Yellow/Yellow on Median) should be installed at spacing's as per the approved drawing.

7.17.3.1.2 Measurements for payment

All barriers will be measured by linear meters of completed and accepted length in place, corresponding end to end along the face of concrete barriers including approach and departure ends.

Rate

The Contract unit rate shall include full compensation for furnishing all labor, materials, tools, equipment and incidental costs necessary for doing all the work involved in constructing the concrete barrier complete in place in all respects as per these Specifications.

7.17.3.2 Metal Beam Crash Barrier/W-Beam

7.17.3.2.1 General

This work shall consist of furnishing and erection of metal beam crash barrier of dimensions and at locations as shown on the drawing(s) or as directed by the Engineer.

Metal beam crash barrier shall generally be located on approaches to bridge structures, at locations where the embankment height is more than 3 m and at horizontal curves.

7.17.3.2.2 Materials

Metal beam rail shall be corrugated sheet steel beams of the class, type, section and thickness indicated on the plans. Railing posts shall be made of steel of the section, weight and length as shown on the plans. All complete steel rail elements, terminal sections, posts, bolts, nuts, hardware and other steel fittings shall be galvanized. All elements of the railing shall be free from abrasions, rough or sharp edges and shall not be kinked, twisted or bent.

The “W” beam type safety barrier shall consist of a steel post and a 3 mm thick “W” beam rail element, spaced away from the posts. The steel post and the blocking out spacer shall both be channel section of 75 x150 mm size 5 mm thick. The rail shall be 70 cm above the ground level and posts shall be spaced 2 m center-to-center.

The thrie-beam safety barrier shall have posts and spacers similar to the ones mentioned above for “W” beam type. The rail shall be placed at 85 cm above the ground level. This barrier has a higher initial cost than the “W” beam type but is less prone to damages by vehicle collisions especially for shallow angle impacts.

The “W” beam, the thrie beam, the posts, spacers and fasteners for steel barriers shall be galvanized by hot dip process (zinc coated, 0.55 kg per square meter; minimum single spot) unless otherwise specified. The galvanizing on all other steel parts shall conform to the relevant Specifications. All galvanizing shall be done after fabrication.

7.17.3.2.3 Construction operations

The line and grade of railing shall be true to that shown on the plans. The railing shall be carefully adjusted prior to fixing in place, to ensure proper matching at abutting joints and correct alignment and camber throughout their length. Holes for field connections shall be drilled with the railing in place in the structure at proper grade and alignment.

Unless otherwise specified on the drawing, railing steel posts shall be given one shop coat of paint (primer) and three coats of paint on structural steel after erection, if the sections are not galvanized. Any part of assembly below ground shall be painted with three coats of red lead paint.

Splices and end connections shall be of the type and designs specified or shown on the plans and shall be of such strength as to develop full design strength of the rail elements.

Installation of posts

Holes shall be dug or drilled to the depth indicated on the plans or posts may be driven by approved methods and equipment, provided these are erected in proper position and are free from distortion and burring or any other damage.

All post holes that are dug or drilled shall of such size as will permit proper setting of the posts and allow sufficient room for backfilling and tapping.

Holes shall be backfilled with selected earth or stable materials in layers not exceeding 100 mm thickness and each layer shall be thoroughly tamped and rammed. When backfilling and tamping are completed, the posts or anchors shall be held securely in place.

Post holes that are drilled in rock and holes for anchor posts shall be backfilled with concrete.

Posts for metal beam guardrail on bridges shall be bolted to the structure as detailed on the plans. The anchor bolts shall be set to proper location and elevation with templates and carefully checked.

Erection

All guard rail anchors shall be set and attachments made and placed as indicated on the plans or as directed by the Engineer.

All bolts or clips used for fastening the guardrail or fittings to the posts shall be drawn up tightly. Each bolt shall have sufficient length to extend at least 6 mm through and beyond the full nut, except where such extensions might interfere with or endanger traffic in which case the bolts shall be cut off flush with the nut.

All railings shall be erected, drawn and adjusted so that the longitudinal tension will be uniform throughout the entire length of the rail.

End treatment for steel barrier and Two-way Trapezoidal Reflectors

End treatments shall form an integral part of safety barriers which should not spear, vault or roll a vehicle for head-on or angled impacts. The two end treatments recommended for steel barriers are “Turned-down-guardrail” and “Anchored in back slope”.

Turned-down guardrails have the “W” or thrie section reduced from full height to ground level with a gentle slope over a distance of 8 to 9 m. The turned down rail is intended to collapse on impact, allowing the vehicle to pass over it without becoming airborne or unstable. In order to locate the barrier terminal away from the traveled way and to minimize drivers’ reaction to hazard near the road by gradually introducing a parallel barrier installation or to transition a roadside barrier nearer the roadway such as a bridge parapet or a railing, the turned down rail should be flared away from the roadway. Suggested flare rates depending upon the design speed and type of barrier are given in Table 7.17-01.

Two-way Trapezoidal Reflectors (Red/White) should be installed at spacing as per the approved drawing.

Table 7.17-01 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

The posts in the end treatment should have the same cross section as provided in the main barrier.

At road cross sections in cutting or if the road transitions from cut to fill, the barriers can be anchored in back slopes. The back slope covering the anchored portion of the barrier should be graded flat, with side slopes preferably not steeper than 10:1. The anchored portion should develop a tensile strength in the rail element to prevent the rail from pulling out of the anchorage. The barrier can also be anchored in an earth beam specially constructed for this purpose provided the new beam itself is not a hazard to the traffic. The earth beam should be made impervious to erosion. No flaring is to be provided for a “Turned-down-guardrail” end treatment.

Tolerance

The posts shall be vertical with a tolerance not exceeding 6mm in a length of 3 m. The railing barrier shall be erected true to line and grade.

7.17.3.2.4 Measurements for payment

Metal beam railing barriers will be measured by linear meter of completed length as per plans and accepted in place. Terminals/anchors of various types shall be paid for by numbers.

No measurement for payment shall be made for projections or anchors beyond the end posts except as noted above. Furnishing and placing anchor bolts and/or devices for guard rail posts on bridges shall be considered incidental to the construction and the costs thereof shall be included in the price for other items of construction.

No measurement for payment will be made for excavation or backfilling performed in connection with this construction.

7.17.3.2.5 Payment

The Contract unit rate shall include full compensation for furnishing of labor, materials, tools, equipments and incidental costs necessary for doing all the work involved in constructing the metal beam railing barrier complete in place in all respects as per these Specifications.

Pay Item No.	Description	Unit
7.17.1	New jersey Barrier	lin m
7.17.2	Metal Beam/W-Beam Barrier	Linear Meter

7.18 Flexible Wire Rope Barriers

7.18.1. General

Flexible Wire Rope Safety Barrier (WRSB) is a type of roadside or median safety traffic barrier/guard rail. It consists of steel wire ropes mounted on weak posts. As is the case with any roadside barrier, its primary purpose is to prevent a vehicle from leaving the travelled way and striking a fixed object or terrain feature that is less forgiving than itself. Also similar to most roadside barriers, cable barriers function by capturing and/or redirecting the errant vehicle. The system is more forgiving.

There are two types of cable barrier systems in use today, low-tension and high-tension. High-tension cable is preferable as when a vehicle impacts the high-tension system under normal conditions, the cable deflects as little as 8 ft from its original location.

High-tension cable consists of three or four pre-stretched cables supported by weak posts. During installation, the cables are placed on the posts, and then tightened to a specific tension according to temperature. The tensions values range between approximately 2,000 and 9,000lb. Due to this tightening, the cable installations can be of indefinite length. In fact, the lengths of the runs are usually only limited by the presence of obstacles such as median openings or bridge columns.

The inherent tension within the system also allows the cables to remain strong, even after an impact that removes several posts, thus allowing the remainder of the run to function normally. But a lack of proper installation and testing has led to severe collisions and even death.

Characteristics

Tension – High tensioned WRSB are generally tensioned to app. 2.5t during installation (subject to weather conditions, type of WRSB, and other factors). Low tensioned WRSB are not as common as they used to be, the tension is generally very low and close to 0.

Containment or Deflection – based WRSB. Deflection aimed WRSB could be tensioned to slightly higher tension and will most probably use 4 wires (ropes). The overall length of the barrier tends to be shorter. Containment based WRSB will have wire ropes spread further apart from each other (approximately 150mm - 60mm), to increase the catchment area.

Test level- FWRB systems should be approved at TL-4 test level.

Slopes-Cable barrier is intended for use on slopes with a 1:6 vertical to horizontal ratio.

Clearance-Cable barriers deflect between 2.5 m and 3.6 m upon impact. Given these relatively large deflections, cable barrier systems are not usually considered appropriate to shield fixed objects closer than 2.5 m offset of the travelled way. Even when the available

clearance exceeds 2.5 m, the public seems to have a greater level of confidence in a more robust barrier.

7.18.2. Material

The system should comply with European (EN) 1317-2 standards or Australian (AS) standards.

(A) POST –

Size– Post shall be 100x55x5mm (Z shaped) hot deep Galvanized.

Height – 1430mm (4.70 Feet) with appropriate length is embedded in underneath concrete for stability.

POST SPACING – Generally 3-5 meter (10.5 Feet) centre to centre, depends on shape of the road. The distance from Final Post to End Anchor is 2 meters (6.5 Ft). As per field condition, supplier will propose the spacing with details and approval needs to be taken from the Engineer in charge.

(B) ROPE -

19mm 3 x 7 strand pre-stretched by 35%

Height of the top Ropes from Road Surface - 790-930 mm [$\pm$ 30mm]

Weight – 1.17 kg/meter.

Minimum Tensile Strength – 1370 N/mm².

Minimum Breaking Load is - 17.7 Tonnes.

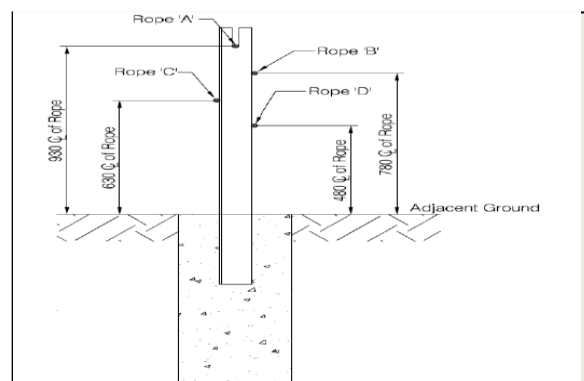
(C) Foundation Pit -

The Foundation Pit size for Posts are 350 mm (1.20 Ft) Diameter x 750 mm (2.460 Ft) deep.

Foundation Pit size for End Anchors are 2000 x 1000 x 3000 mm Diameter or 1500 x 1500 x 1500 mm or between 3 to 6 cubic meters in volume depending upon the soil conditions.

Concrete strength needs to be 25Mpa.

A typical drawing is given below-



7.18.3. Installation

The tension is applied using a tension machine and hand-pump, to achieve the correct level of tension on the wire ropes, during installation. All other installation procedure will be according to EN 1317-2 standards or AS or Manufacturer standard procedure, as recommended by the Engineer in Charge.

End protection, painting and Delineators

2-way (red and white) Reflectors should be installed on all posts or top of all posts should also be painted with red-colour reflective paint. Also Glare Protection and a tough plastic sheet have to be provided post to post to reduce motor-cycle rider casualties.

Post caps shall be fitted with 50 x 100 mm Class 1A retro: reflective material or placed on the front top of the post above the wire ropes. Delineators shall be installed at approximately 12.5 to 15 m spacing. Delineators shall not be placed on flared sections.

All other safety measures will be according to EN 1317-2 standards or AS or Manufacturer standard procedure, as recommended by the Engineer in Charge.

7.18.4. Measurement

The quantity to be measured for payment shall be the number of linear meters of Wire rope Barrier completed, including the supply and installation of all ropes, posts, anchorages and fixings as specified.

7.18.5. Payment

This work measured as provided above will be paid for at the Contract rate for Wire rope Barrier. The rate and payment will be full compensation for furnishing and installing all materials, including labor, equipment, tools and incidentals necessary to complete the work.

Pay Item No.	Description	Unit
7.18.1	Wire Rope Barrier	Linear Meter

7.19 Water Filled Plastic Movable Barriers with Reflectors

7.19.1. Description

Since our water filled barriers are constructed with high-quality Polyethylene plastic, the hollow construction is perfect for any construction site. The water filled barrier is lightweight when empty but provides excellent stability and energy absorption when filled with water. Since we know that your construction project demands the best equipment, we have designed our barriers to be highly durable and resistant to splitting, cracking, and deterioration even in inclement weather. Water filled barriers are a great alternative to traditional barricades because they provide energy absorption for

Oncoming traffic in a way that provides increased safety for both drivers and workers. These practical and economical applications make water filled obstacles one of the most popular options for work zone places nowadays. In virtually any construction zone there is always an essential balance to be struck between protecting motorists and protecting workers. The forces from impact having a water barricade upon passengers and automobile are significantly lower compared to the choice that is concrete, yet a barricade that is ballasted does the occupation of protecting workers in the area. Water filled barriers are a great alternative to traditional barricades because they provide energy absorption for oncoming traffic in a way that provides increased safety for both drivers and workers. These practical and economical applications make water filled obstacles one of the most popular options for work zone places nowadays.

7.19.2. Use/Application

Road Safety Barriers are used on Roads to control the Motorists to not to move to Restricted areas, it is also used to stop the vehicle, to direct the vehicles to other path, in construction sites etc.

Water filled barriers can be used in the following situations

- a. Construction areas
- b. Work zones
- c. Crowd control
- d. Temporary road blocks
- e. Public works projects
- f. Special events/sporting events
- g. Traffic Channelizing

7.19.3. Materials & Properties

Plastic water filled barrier, Reflector tape

7.19.4. Construction

The construction crews will appreciate how easy it is to transport and set up the water filled barriers. All tasks can be easily be carried out by a two-man team is afforded by the lightweight of empty obstacles and is ideal when temporary restrictions are needed fast. Deploying water filled barriers allows for rapid response in emergency situations, as well as adequate security on a temporary basis.

To ensure maximum safety for traffic and construction crews, our barriers are made using highly visible colors to be seen in all weather and conditions. Particularly essential for temporary obstacles, which frequently present an ‘unexpected’ element for motorists and pedestrians, for example when used to delineate diversions and temporary closings and reflectors.

Using their range of high visibility colors, water filled barriers are certainly evident from a safe space, to improve safety in comprehension, along with accessibility.

7.19.5. Warranty

- a. Length: 1000 mm
- b. Height: 800 mm
- c. Width: 500 mm
- d. Maximum Capacity of Water: 20 Liters
- e. Material Pure HDPE,
- f. UV Protected
- g. Reflectors on Water filled Road Barrier.

7.19.6. Measurement

The quantity to be measured for payment shall be the number of linear meters

7.19.7. Payment

Pay Item No.	Description	Unit
7.19.1	Plastic Movable Barriers	Linear Meter

7.20 Cones with Retro-Reflective Sheets and connected by Ropes

7.20.1. Description

Safety Cones are also called as Traffic cones, Construction cones, Witch's hat, Road cones which is generally a conical marker used on roads or highways. Traffic cones are generally placed on roads to warn drivers not to drive too close to an area where work is being done. Safety Traffic Cones are used in directing traffic, indicate special routes, use at sporting events. Safety Cones are also used to delineate short-duration maintenance and utility work. By using the Safety Cones Traffic management can be done and happening of unnatural incidents near maintenance and utility works can be avoided.

7.20.2 Use/Application

Specifically designed to be provided on roads and highways to fulfill a variety of application from safety point of view like Lane dividing, Road diversion, Parking areas, Men at work zone, Traffic channelization.

7.20.3 Materials & Properties

- a. Made of special PVC material that makes them highly flexible and durable.
- b. A high reflective sleeve is fixed on the cone for better visibility in all weather conditions.
- c. It also has provision for fixing of "O" Ring, plastic chain or caution tape.
- d. Uniquely designed base absorbs impact, grips the road and won't easily blow off with fast traffic or winds.
- e. Brilliant fluorescent red Color which is UV tempered and attracts immediate attention.
- f. Textured interior surface prevents stacked cones from sticking together.
- g. Provision of holes for fixing plastic chain, Bright color UV stabilized, Reflective sleeve for day night visibility, excellent flexure strength, Sturdiness, Durability, Widely used for road safety.

7.20.4 Construction

It is portable.

7.20.5 Warranty

- a. Material: Premium grade 100 % PVC
- b. Height: 750 mm
- c. Base: 320 mm
- d. Rubber Base Thickness: 25.4 mm
- e. Reflective Sleeve: White PVC Sleeve of width 100 mm
- f. Weight: 1.9 Kgs

7.20.6 Measurements

The quantity to be measured for payment shall be the number of each cone

7.20.7 Payment

Pay Item	Description	Unit
7.20.1	Cones	Nos

7.21 Fencing for Footpath / NMT Lane Separator

7.21.1 Description

The work consists of furnishing all materials for constructing fencing concrete foundations. The work includes the furnishing and placing of foundation concrete and all other incidental necessary and devices used to fix and erect the fencing as per contract drawings or directed by the Engineer.

7.21.2 Materials

A mild steel to be used in such to AASHTO standard: M 183-93. Fencing for footpath / NMT lane separator should be painted and finished with two coats of synthetic enamel paint of approved color and quality over one coat of anti-corrosive primer to provide a smooth painted appearance.

7.21.3 Installation

The fencing shall be carefully adjusted, installed or erected over 1:2: 4 cement concrete foundation blocks of specified dimensions truly vertical and in longitudinal profile as approved by the Engineer. The same shall be supported and protected appropriately at least for 3 (three) weeks, till foundation concrete hardness after full curing during this period is attained.

7.21.4 Measurement

The footpath / NMT lane separator fencing shall be measured in linear meters actually constructed and accepted in conformity with size, shape and design/details as shown on the drawings or as directed by the Engineer. The length, however, shall be measured along the centre line of top of the fencing.

7.21.5 Payment

Fencing as measured above shall be paid in the contract unit price linear meter. Rate shall be the full compensation for furnishing all labor, carriage, all materials, tools and plants, welding and painting excavation, cutting pavements, cement concrete foundation curing and protection of works, disposing off of surplus excavation material, backfilling and all other incidentals necessary to complete the work.

Pay Item	Description	Unit
7.21.1	Fencing for Footpath, height 1.5m	Lin. m
7.21.2	Fencing for NMT lane separator, height 1.5m	Lin. m

7.22 Raised Pedestrian Crossing on Speed Table/ Speed Hump

7.22.1 Description

Raised pedestrian crossings on Speed tables are also used as speed reducer to the vehicles. Speed tables are trapezoidal devices over an extended width enabling traffic to pass through at higher speeds ranging from 30km/h to 60km/h. They consist of a flat top and two approach ramps. In view of this raised pedestrian crossings are provided in the selected bazar areas, in front of the School, College and University where vehicles pass at considerable speed. Besides, raised pedestrian crossings are also provided in some critical areas where vehicles have the options of passing at high speed.

The width of pedestrian crossings is generally in the order of 3m to 5m. Pedestrian crossings may be located on or in between speed tables. Where traffic flow is heavy and speed is around 30km/h, pedestrian crossings on speed table are particularly attractive if there is already a footpath. Where traffic flow is heavy and speed is around 40 to 50km/h, pedestrian crossings may be located between speed tables. Where traffic flow is moderate and speed is low with busy pedestrian activities, pedestrian crossings may not be required.

Speed humps are sinusoidal device over an extended width enabling traffic to pass through at higher speeds ranging from 30km/h to 60km/h.

7.22.2 Materials

7.22.2.1 Tack Coat

Liquid asphalt for tack coat shall be rapid-curing type cutback grades RC-2 or RC-4 or as directed by the Engineer, and shall conform to the requirements of sub-clause 4.4.2 of this specification. Bituminous tack coat shall be applied on the existing bituminous surfaces where rumble strips/raised pedestrian crossing will be constructed.

7.22.2.2 Bituminous Mixture

The bituminous mixture for Raised Pedestrian Crossing shall be Premix Bituminous Carpeting shall conform to the requirements for clause 4.5 premix bituminous carpeting of this specification.

3% of cement shall be used in bituminous mixture as filler to improve the strength of completed Raised Pedestrian Crossing.

7.22.2.3 Form Work

Steel forms shall be used for construction of Raised pedestrian Crossing. Forms shall be placed on the road surface tightly so that shape of the works is obtained as per drawings.

7.22.3 Construction Methods

7.22.3.1 Surface Preparation

Immediately prior to the application of the tack coat, the bituminous surface shall be cleaned free of all dirt, dust, and other foreign substances which, in the opinion of the Engineer, would prevent proper bonding of the tack coat. For the case of rumble strips chipping shall be done on the existing road surface for ensuring bond up to satisfaction of the Engineer.

7.22.3.2 Application of Tack 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 exceed one-quarter (1/4) liter per square meter. The tack coat shall be applied uniformly and to the satisfaction of the Engineer.

7.22.3.3 Placing of Bituminous Mixture

As soon as the tack coat has set hot bituminous mixture shall be placed in the forms and consolidated by approved hand methods and struck flush with the top of the form.

7.22.3.4 Compaction of Bituminous Mixture

For the case of rumble strips bituminous mix shall be consolidated by hand compactor/hand roller. Forms of rumbles strips shall remain in place until the premixed bituminous materials has properly consolidated and pre-compacted so that shape of the rumble strips is not distorted after removal of the Forms. Rumble strips damaged partially or fully during removal of the Forms and allowing vehicles passing over, the contractor shall redo the rumble strips at his own cost.

For the cases of speed reducers and raised pedestrian crossings bituminous mixture shall be compacted with different method. After the bituminous mixture has been placed in the form and consolidated, the form shall be carefully removed from the roadway and rolling operations shall immediately be started with an approved pneumatic roller/vibrating roller as per direction of the Engineer, Rolling shall be continued until the desired compaction is obtained. Turning of roller on the work shall not be permitted. After completion of rolling operations, all visible tack coats if any shall be blotted with sand.

7.22.4 Measurement

Raised Pedestrian Crossings shall be measured in contract unit rate per cubic meters actually completed and accepted by the Engineer. Dimensions of rumble strips and raised pedestrian crossings shall be measured after acceptance.

Bituminous tack coat shall be measured separately as stated under the item 3.7.1 of these specifications.

7.22.5 Payment

The payment shall be the full compensation for all materials, labor, equipment, tools, supplies and incidentals for completion of the work.

The pay items shall be:

Pay Item	Description	Unit
7.22.1	Raised Pedestrian Crossing	Cubic Meter
7.22.2	Speed Hump	Cubic Meter
3.7.1	Bituminous Tack Coat	Square Meter

7.23 Rumble Strip (Thermoplastic)

7.23.1 General

A rumble strip is an installation on the pavement consisting of indentations which generate an audio-tactile effect to alert drivers when it is driven over. When a vehicle drives over them, they make a loud rumbling sound and vibration. They can be placed across traffic lanes to alert drivers that they are approaching a potentially hazardous location, such as a work zone or an isolated intersection. They are used along the shoulders or centerlines of highways to alert drivers that they are leaving their traffic lane.

Types of rumble strips

a) Longitudinal rumble strip

Longitudinal rumble strips provide an effective warning to road users who may stray away from their travel paths due to fatigue, inattention, errors in judgment or poor visibility in rain or fog. If not corrected in time, this could lead to the vehicle crashing onto the roadside or colliding with a stopped vehicle on the shoulder. Rumble strips are particularly beneficial in a rural environment and may be installed along:

- a. edge lines and shoulder lines
- b. centerlines and wide center lines
- c. chevron markings preceding a diverge gore

However, it should not be placed on the shoulder of a roadway that is used by bicyclists unless a minimum clear path of 1 meter is also provided on the shoulder. On divided highways, rumble strips are sometimes installed on the median side (left-hand side) shoulder as well as on the outside (right-hand side) shoulder. On two-way roadways, rumble strips are sometimes installed along the center line.

b) Rumble strip median

Rumble strip median is provided to carriageway for separating traffic flow. It is constructed by premix bituminous carpeting materials with seal coat at the same time will be measured in linear meter actually constructed and accepted in conformity with size and details as shown on drawings or as directed by the Engineer.

c) Transverse rumble strip

The main purpose of transverse rumble strips is to reduce traffic speeds and raised awareness on the approach to intersections, roundabouts, pedestrian crossings and urbanized sections etc. They are also useful on the approach to sharp curves, tunnels and toll plazas on free-flow sections of single and dual carriageway roads. They should be used in conjunction with traffic signs unless the hazard is self-explaining.

Detailed dimensions of transverse rumble strips are given in the Engineering drawings. Rumble strips shall be provided on the Highways to aware the drivers about speed reducer, raised pedestrian crossing and rail crossing ahead. 6-9 strips shall make a set of rumble strips and two sets of rumble strips shall be required. Distance of the Rumble Strips from the obstructions and distance in between each set of Rumble Strips vary depending upon speed limits of the vehicles. Table 07.23-01 shows the distances at different speed limits.

Table 07.23-01 Distance of the Rumble Strips from the obstructions and in between each set of Rumble Strips

Speed Limit (km/hr)	Distance (L) in between the strips (Vehicles will cross first) and the obstruction. Distances are in meter (m)	Clear distance (L1) in between two sets of Rumble Strips. Distances are in meter (m)
40	100	25
50	125	30
60	150	35
70	175	40
80	200	45

Before commencing the physical works of the Rumble Strips the contractor shall give layouts of the required rumble strips and get approval of the Engineer. The Engineer has the authority to change the above distances and number of strips.

7.23.2. Material

Same as 7.5.2 from this specification

7.23.3. Placement

Same as 7.5.3 from this specification

7.23.4. Measurement

Same as 7.5. 5from this specification

7.23.5. Payment

Same as 7.5.6 from this specification

7.24 Rumble Strip Tape/ Pavement Marking Tape

7.24.1. General

Pavement Marking Tape is a high visible and durable reflective tape. Pavement marking tape with a polyurethane top coat is applied for long term high dry brightness to retain whiteness and a reinforced netting for added long life. These tapes can be applied without surface preparation adhesive during the typical pavement marking season. These tapes are ideal for use on asphalt or concrete surfaces and on dark roads where reflectivity is critical during the night. These are preformed reflective tapes for permanent-type applications such as lane and center lines, edge lines, gore markings, crosswalks, stop bars, symbols and legends.

Requirements

Adhesive Type	Permanent
Average Daily Traffic	High, Medium
Construction	Pre-formed patterned tape
Design Pattern	Raised diamond pattern
Surface Type	Asphalt, Concrete
Width	100 mm

7.24.2 Installation

Installation will be done as per Manufactures standard guidelines or as per instruction of the Engineer in charge.

7.24.3. Measurement

The quantity to be measured for payment shall be linear meter

7.24.4 Payment

Pay Item	Description	Unit
7.24.1	Rumble strip tape	Lin Meter

7.25 Convex Mirror

7.25.1General

Convex mirrors are used for safety reasons to overcome sight restriction problems. Their use is now widely accepted in low-speed vehicle and pedestrian conflict areas. Convex mirrors are typically used where the lateral sight distance is poor at locations such as obscured T- junctions, concealed driveways, acute bends of a narrow road, such as hairpin bends in mountain passes, parking areas with acute exit driveways, or approaches to skewed railway level crossings. The convex mirror is also known as the spherical mirror, wide-angle mirror, it is mostly placed or installed in a variety of corners and junctions. It can expand the driver's vision so as to detect the corners across the vehicle early to reduce the occurrence of traffic accidents. And it also can serve as a monitor if installed in the street corridors and shops.

Precaution

However, convex mirrors should not be used as the first option when sight distance is restricted. Convex mirrors should only be used in low-volume, low-speed road environments. The traffic being viewed in the mirror should have an 85th percentile speed of 60 km/h or less.

Convex safety mirrors shall not be installed:

- a) On public roads where alternative traffic management measures or engineering measures such as improvements to sight distance and road-realignment are available in the short term.
- b) To enhance the safety of pedestrian crossing movements. Other solutions should be considered, such as relocation of the crossing point or strategically located pedestrian refuges.

Convex mirrors are not for general use 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. A road safety audit should be conducted before a decision is made to install a convex mirror on a public road.

7.25.2 Material

Properties

Convex mirrors should have following features:

- a. offer bright reflection
- b. unbreakable and unalterable
- c. easy to install
- d. durable
- e. vandal resistant
- f. weather proof material
- g. resistant against abrasion
- h. corrosion resistance

Material/ Product Details

Body Material	highly polished stainless steel or polycarbonate
Size	45 cm/60 cm/80 cm/100 cm
Lens	Polycarbonate with Hood
Shape	Circular

7.25.3 Installation

Installation will be done as per Manufactures standard guidelines or as per instruction of the Engineer in charge. These mirrors can be fixed in different angles as per the need, used to see the images of vehicles from blind spot and prevent accidents.

The ‘DISTORTED IMAGE’ written sign must be installed below the mirror. An advance sign ‘CONVEX MIRROR AHEAD’ also be required if the location of the convex mirror is not obvious.

7.25.4. Measurement

The quantity to be measured for payment shall be the number of each Convex Mirror

7.25.5 Payment

Pay Item	Description	Unit
7.25.1	Convex Mirror	Nos

7.26 Anti-Glare Systems

7.26.1 Description

Anti-glare systems are facilities to limit the glare of headlights from opposing vehicles or other external light sources. Anti-glare screens are installed on the roads and designed to prevent a driver against glare from headlights of an oncoming vehicle. The main reasons for using and installation of anti-glare screens on the roads are road sections with dangerous and sharp turns, accidents at dusk and at night, unfavorable terrain.

7.26.2. Material

Materials should confirm European standards EN 12676-1, EN 12676-2 or as per Clients requirement.

The main structural element is a robust blown plate made of low pressure high molecular weight polymer which is painted with non-fading stain and resistant against UV radiation.

- a. Plate height: 600 mm, 900 mm, 1200 mm.
- b. Plate width: 220 mm, 267 mm.
- c. Wear-resistant, resistant against corrosion and UV radiation, various chemical agents, various environmental influences. Product operation is acceptable at the temperatures between -40 and +60 degrees.
- d. Wind load on the system structure is 150 km/h.
- e. Anti-glare screens have no sharp corners on which the people can get hurt.

7.26.3 Application

Anti-glare systems should be considered mainly on Expressway and National Highway roads in the following situations:

1. Narrow Median width
2. Relatively heavy night time traffic
3. Low standard horizontal curves and sag curves
4. Opposing traffic at a different level smaller than 2m
5. Existence of a parallel road with opposing traffic
6. Near tunnel portals where tunnel tubes are at close proximity
7. Glare from other light sources

At intersection, median openings and pedestrian crossings, anti-glare systems have to be terminated well in advance to satisfy visibility requirements.

Requirements

The height of anti-glare systems is generally in the order of 1,400mm above the pavement. The width of anti-glare screen is in the range of 80 to 250mm at a spacing of 0.5m to 1.0m.

Anti-glare screens should be able to shield opposing traffic headlamps at an angle not less than 8 degrees. On horizontal and vertical curves, the minimum angle should be increased to the range of 8 to 15 degrees.

Anti-glare facilities on curves should not result in unacceptable forward visibility required for the prevailing operating speeds of traffic. Otherwise, the median has to be adequately widened.

Precaution

Anti-glare screens or nets should not be made of reflective materials. They may be attached onto safety barriers without compromising their normal safety function.

7.26.4. Measurement

Installation will be done as per Manufactures standard guidelines or as per instruction of the Engineer in charge.

7.26.5. Payment

The quantity to be measured for payment shall be in linear meter

Pay Item	Description	Unit
7.26.1	Anti-Glare Screen	Lin Meter

7.27 Sound Barrier

7.27.1 General

Modern highways are a source of noise of rather a high frequency rate (ranging from 63 to 8000 Hz) that significantly exceeds the acceptable sanitary and hygienic norms for surrounding areas. There are a lot of scientific works on the issue of the harm of noise loads for living forms; therefore noise screens within populated places, recreation spaces and other adjacent inhabited areas are compulsory.

Requirements and conditions

- a. Acoustic design
 - correct acoustic calculations to determine the geometric dimensions, configuration and location of barriers
- b. Construction design
 - according to the requirements of acoustic design for the barrier geometry taking into account the geology, geodesy and wind region norms, an economical version of the foundation should be developed;
- c. Using of high-quality structural elements
 - mandatory anti-corrosion protection for all metal parts
 - acoustic elements in the barrier structure should have an acoustic insulation factor not less than 24 dBA
- d. Installation
 - correct installation is an important factor under assembly of barrier structure
 - Need to avoid discontinuity in the barrier body (the exception – using of additional acoustic barriers), cracks and gaps both in the structure itself, and between the structure and the roadbed.

7.27.2 Materials

Materials with Types

Noise barrier is a structure composed of:

- a. Foundation;
- b. Metal supports;
- c. Acoustic structural elements;

- d. Seals and fasteners.

Noise barriers are divided into two types – noise reflective (transparent and non-transparent) and noise absorbing (non-transparent, with a mineral wool filling) systems.

Noise Barrier Screens

The main structural unit is a noise barrier panel. The panel is made of galvanized metal from 0.7 to 1.2 mm thick and later it is coated with a polymeric coating. The panel has the shape of a box and is filled with mineral wool (with density ranging from 75 to 175kg/m³) in a waterproof film.

The noise barrier panel may have no perforations or may have a perforated front side that increases the absorption ability (absorption factor).

Reflective Noise Screen

The main structural unit is a reflective sound case manufactured of acrylic glass or monolithic polycarbonate (with a fatigue limit not less than 60MPa and a light-transmitting ability not less than 88%). Due to the high light-transmitting ability the reflective noise screens allow surveying and prevent from the tunneling effect.

Combined Screens

The construction includes noise barrier panels combined with reflective sound boxes.

7.27.3 Constructions

Installation will be done as per Manufactures standard guidelines or as per instruction of the Engineer in charge.

7.27.4 Measurement

The quantity to be measured for payment shall be in linear meter

7.27.5 Payment

Pay Item	Description	Unit
7.27.1	Sound Barrier	Lin Meter

7.28 Street Lighting

7.28.1 General

Street lighting should be provided as a priority:

- a. Within built-up areas and their peripheries

- b. For road sections with sub-standard alignment
- c. For road sections with heavy traffic at night time
- d. For road sections with regular pedestrians or slow traffic at night time
- e. For grade-separated pedestrian or slow vehicle facilities
- f. At major interchanges or intersections with heavy traffic at night time
- g. Through tunnels, long bridges and their immediate approaches
- h. At toll plazas and immediate approaches to ports or border control points

General Requirements

The recommended luminance performance of street lighting is given in Table 7.28-1.

Table 7.28-1: Recommended Luminance Performance of Road Lighting

Recommended Luminance Performance Category	Average Luminance Level L (cd/m ²)	Overall Uniformity Ratio U ₀	Longitudinal Uniformity Ratio U ₁	Road Categories
1	1.5	0.4	0.7	Expressway and National Highway Roads with speed limit ≥ 70 km/h
2	1.0	0.4	0.5	Other rural or urban roads
3	0.5	0.4	0.5	Connecting roads of less importance

L: Average luminance over a defined area of the road surface viewed from a specified observer position

U₀: Ratio of the minimum to average luminance of a defined area of the roadway

U₁: Ratio of the minimum to the maximum luminance along a longitudinal line drawn through the observer position

7.28.2 Material and Equipment

- a. Urban Traffic Routes, Main Distributor Roads – Generally 10 meter mounting height column supporting LED luminaires as appropriate to meet the requirements for the appropriate ME lighting class.

- b. Industrial Estate, Local Distributor and Access Roads – Generally 8-10 meter mounting height column supporting LED luminaires to meet the requirements for the appropriate lighting class.
- c. Residential Roads Access Roads and Footpaths – Generally 6 meter mounting height column supporting LED/ as appropriate to meet the requirements for the appropriate S lighting class.

7.28.3 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 1925, Electrical Department guidelines etc.)

Installation will be done as per Manufactures standard guidelines or as per instruction of the Engineer in charge.

7.28.4 Warranty

Provide a written five year on-site replacement warranty covering material, fixture finish, and workmanship.

On-site replacement includes transportation, removal, and installation of new products. Finish warranty shall include warranty against failure or substantial deterioration such as blistering, cracking, peeling, chalking, or fading. Provide a written five year replacement material warranty for defective or non-starting LED source assemblies. Provide a written five-year replacement material warranty on all drivers (power supplies). Provide a written five year replacement warranty for luminaires exhibiting inadequate lumen maintenance at end of warranty period. Warranty period shall begin on date of possession. The supplier will provide the site Owner with appropriate signed warranty certificates. The site Owner shall receive certificates prior to final payment.

7.28.5 Measurement

The quantity to be measured for payment shall be after completed work

7.28.6 Payment

Pay Item	Description	Unit
7.28.1	Road Lighting	On Completed work

7.29 Distance Marker (KM Post)

7.29.1 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.

7.29.2 Materials

Concrete kilometre posts shall be precast using concrete conforming to the requirements of Section 7.10.2.1.3. Reinforcement steel shall conform to the requirements of related Section. Paint, if indicated on the Drawings, shall be of the appropriate type and color and to the approval of the Engineer.

7.29.3 Construction Methods

Construction, fabrication and installation of concrete kilometre posts shall be as shown on the Drawings.

7.29.4 Measurement

The quantity measured for payment shall be the actual number of concrete kilometre posts placed and accepted.

7.29.5 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 Item	Description	Unit
7.29.1	Concrete Kilometer Posts	On Completed Work Each Nos

7.30 Traffic Impact Attenuators

7.30.1 General

The work shall include configuration, furnishing and installing traffic impact attenuation devices at hazardous locations (for example gore areas between diverging roadways) conforming to the details shown in the drawings/plans or as directed by the Engineer; so as to act as energy absorbers. The traffic impact attenuators or crash cushions shall be installed for speeds greater than 50 kmph. They may be composed of sand barrels or of 'w'-beam fender panels supported by diaphragm with trigger mechanism.

7.30.2 Material

The system shall consist of a group or series of free standing plastic barrels configured in increasing weights from the impact point towards the object. The array shall be designed to transfer the vehicle's momentum to the increasing masses of sand in the barrels and to provide a gradual deceleration. Each barrel is to be designed with a specific weight of unbagged sand to absorb the energy of an errant vehicle. The lighter barrels shall be placed near the front of arrays to gradually slow the smaller vehicles. Heavier barrels shall be placed further back in the array to slow the larger vehicles. The standard module weights are 90 kg, 180 kg, 315 kg, 640 kg and 950 kg, as recommended by AASHTO. The axis of symmetry of the arrays should be directed along the most likely direction. Approach for an errant vehicle for gore areas could be back towards the intersection of the edges of pavement. For roadside hazards, the angle between access of the array and the edge of the travelled way should not 10°. Obstacles in narrow median should be shielded on both ends and the modules placed on the ends (to shield opposite direction traffic) should be placed flushed with downstream edge of the obstacle to avoid wrong way hits. The modules should be placed on a concrete or asphalt surface with maximum slope of 5 percent in any direction. Each barrel's location and weight of sand should be carefully spray painted on the surface at the position that will be covered by the barrel to ensure that the array will be correctly reconstructed after an accident.

7.30.3 Application

The total length and width of the array shall be designed depending upon the expected speed of approaching vehicle. The typical lay out for approach speed of 100 kmph would have total length of 10 m, width of 2.5 m accommodating 14 barrels arranged in 9 rows with one barrel in first 4 rows and 2 barrels in next 5 rows. The Contractor shall furnish a copy of the manufacturer's installation instructions for whatever particular brand of sand-filled impact attenuator is to be used. The sand-filled impact attenuator arrays shall be inspected to ensure that the array is set up as shown in the standard plans and filled in accordance with the manufacturer's recommendations. Sand barrels are essentially one-hit systems requiring complete replacement of impacted barrels. Their use, therefore, is suitable at sites where impact frequency is expected to be low. The arrangement shall be first designed and the layout drawing got approved by the Engineer.

Proprietary Attenuator System

The Proprietary Attenuator Systems essentially comprise a series of w- beam fender panels supported by diaphragms with a trigger mechanism at nose, which, when hit, releases a 'front assembly' to absorb the energy of impact. When impacted, the system shall telescope rearward to absorb the energy so as to bring the errant vehicle to a controlled stop. The refurbishment shall involve the replacement of damaged unit with repair done, off site. The contractor/supplier of such system shall furnish the certificate that the system to be installed has been tested in accordance with the NCHRP 350 and performs effectively at design speeds up to 100 kmph

7.30.4 Measurement

The quantity to be measured for payment shall be after completed work

7.30.5 Payment

The traffic impact attenuator system shall be measured and payment made for design and installation of the system as complete job at each location.

Pay Item	Description	Unit
7.30.1	Impact Attenuator	on completed work

7.31 Semi Automatic Toll Collection System

The Integrated Semi-Automatic Toll Collection System shall comprise following main subsystems:

- a. Automatic Vehicle Counter cum Classifier (AVCC)
- b. Automatic Boom Barrier
- c. Contactless Smart Card Systems
- d. Ticket Printer
- e. User Fare Display unit
- f. Close Circuit Television System (CCTV)
- g. Lane Controller
- h. Traffic Light System
- i. Intercom System
- j. Over Head Lane Signs
- k. Integrated Toll Management Software

All equipment shall have built - in or external surge protection devices.

7.31.1 Automatic Vehicle Counter cum Classifier (AVCC) System

General

The AVCC system shall be able to distinguish between the categories of vehicles using the highway and as defined by the Ministry's Toll Rules. This class information shall be transmitted to the Lane Computer on completion of the post Automatic Vehicle

Classification (AVC). The Lane Computer shall check that this information matches the classification entered by the toll collector. If there is a discrepancy between the two classifications, the Lane Camera shall be triggered to capture a digital image of the vehicle together with details of the class discrepancy message, transaction number with its date and time, lane number and toll collector. The digital image and discrepancy information shall be communicated to the supervisory console for further processing by the toll supervision staff. In case of network or Lane computer failure, the AVCC system shall function independently and feed data directly to the Plaza Server and the system shall be able to detect the vehicle moving in wrong direction. The system shall also assist in auditing the toll collection operation. It shall be in modular unit with capability for various modules and functions to perform independently at different levels of toll collection operation. The Central AVCC data base system shall be part of this audit function. It shall be a standalone device with control access where the data cannot be changed or altered in any way. The reports from this system shall assist in identifying problems with operations, fraud or over/under collection of tolls. This central AVCC database System shall be able to operate independently of the Toll Lane System, even if the Toll Lane Controller is non-operational. Any new technology, meeting the requirements specified in these Specifications should not be excluded.

Technical requirements

Each lane shall be equipped with an AVC controller (different from the lane controller) interface to classification sensors. The classification sensors can be any or combinations of the following types:

- a. Fiber-optic treadles
- b. Laser classifiers
- c. Optical height sensors
- d. Optical axle counters
- e. Infrared Light curtains
- f. Magnetic Sensors
- g. Resistive Sensors

AVCC processing unit shall be a real-time processing unit shall be the trigger source for Lane Camera system and shall have standby power supply capable of operations for a period of at least 4 hours. The AVC controller should be metallic, vandal-proof with IP 65 protection. It shall have System accuracy (calculated on a base of 10,000 vehicles)

- a) For vehicle counting: 99% minimum.
- b) For vehicle classification: 98% minimum.

7.31.2. Automatic Boom Barrier

General

The barriers are to be used to control the traffic through the lane. The operation of boom barrier shall be linked to the lane computer and shall allow the vehicle to pass through after

a successful financial transaction. The system shall consist of a fixed housing and a movable arm. The boom shall be of 3000 mm length for a normal lane and more than 3500 mm for extra wide lane. The housing shall contain the motor and control units and shall be installed on the left side of the lane. The boom barrier should be electrically operated barrier gate for Toll Lane application. The barriers shall have presence detectors independent to the AVC system to prevent barrier arms coming down on vehicles while passing. This shall be in the form of infrared units, dedicated embedded loops or any other sensors. The finish of its housing may be Powder Coated Orange, RAL 2000 and that of the boom with powder Coated White RAL 9010 with reflective strips. All housing and internal parts shall have rust and corrosion free metals or alloys of high strength with suitable epoxy coating as applicable. The Housing base frame shall be of Stainless Steel so as to protect the housing from rusting from the bottom.

Technical requirement

The power supply shall be through 230+/-10%V AC, 50Hz with 100 percent duty cycle. Its Logic Control shall be with Technology to ensure that opening and closing timings remain constant under variation of wind and speed. It shall have smooth landing of boom without swaying at the end positions. The response time shall be 1.5 seconds, for boom length of up to 3000 mm and 2 sec. for boom length more than 3500 mm. The mean time before failure (MTBF) shall be 5 million cycles (1 Cycle = 1 open and close). It should be able to operate between the temperature ranges of -5°C to 55°C.

Lane Camera

General

The camera installed at convenient location shall be capable of capturing images of the following vehicles:

- a) In case of class discrepancy between the class detected by the AVC and that entered by the toll collector
- b) Exempt users
- c) Vehicles with Smart card
- d) All transaction of vehicle with special events
- e) Offending vehicles
- f) When the alarm footswitch is activated by the toll collector.

System Configuration

The camera should be installed at convenient location to capture images of the vehicles; it shall produce clear images of the front view along with the number plates of the vehicles even during night. The resolution of the images should be such that the registration number of the vehicles can be easily read. The camera should have waterproof housing with a hood to protect from direct sunlight. The protection shall be in accordance with IP65. The stand

for the camera shall be made in steel tube that will not swing or twist under gutter speed of strong wind.

7.31.3 Contactless Smart Card Readers/Writers

General

The Contactless Smart Card Readers/Writers are used for managing electronic Toll Collection in conjunction with a compatible Contactless Smart Card. The Contactless Smart Card Readers/Writer is linked to a micro-controller or a PC which is typically the lane computer. It allows the vehicle to pass through after a successful financial transaction. Card reader/writer shall be “single-package” type, combining electronics and antenna in one package.

Installation requirement

The Contactless Smart Card Readers/Writers shall be installed on the right side of all the lanes of the Toll Plaza. The orientation of the Contactless Smart Card Readers/Writers shall be wall mounting type, to be at a suitable height on the toll booth wall, to accommodate all types of vehicles e.g. separate readers for trucks/buses and cars/jeeps. This is to ensure that a successful ‘Readers/Writers’ is achieved with a Contactless Smart Card. Readers/Writers.

Technical requirements

The reader shall have the ability to read the smart card from a distance, ranging from 0 cm to 10 cm with a transaction time of less than 0.5 seconds for read/write. Contactless Smart Card Readers/Writers shall be wall mounting type and all transactions shall be secured with modern and industry standard cryptographic techniques or those based on DES/3DES mechanisms to resist fraud and to deter theft or misuse. The reader/writer shall conform to ISO Standards: 14443A and shall be sealed to a NEMA 4/IP65. It should have transmit frequency of 13.56 MHz The operating temperature of the Smart Card Readers/Writer should be -5°C to +55°C and operating humidity of up to 95 percent non-condensing.

Contactless Smart Cards

General

The Contactless Smart Card is used for storing money value for the purpose of Toll Collection in conjunction with a compatible Contactless Smart Card Readers/Writers. The Contactless Smart Card allows the Readers/Writers to increment/decrement user fee from the stored money value. It allows the vehicle to pass through after a successful financial transaction. The Contactless Smart Card, the card Readers/Writers shall be in a single technology configuration. The Smart Card shall be able to store the money value in prepaid mode.

Technical requirements

The card shall meet the ISO 14443A standards for contactless smart cards. The memory of the smart card shall be $\geq 1\text{KB}$. It shall be warranted against defects in materials and workmanship for 3 years. The Operating Temperature of the Smart Card should be -10°C to 60°C .

7.31.4 Close Circuit Television (CCTV) System

General

The System shall be provided to monitor the activities of toll collection booth operations in the toll plaza. It shall comprise Video Camera and Video Camera Housing at the toll Plaza and 42" LCD Monitor and Digital Video Recorder (DVR) at the control centre. The Video Cameras shall be conveniently mounted so that full view of the Toll Plaza and the booth operations are captured.

Technical requirements

The Video Camera shall be of dome type to avoid pilferage, be resistant to vandalism and be weather-proof. The mounting and equipment housing shall be able to withstand adverse weather conditions the camera shall provide a minimum of 520 TV lines horizontal resolution. The camera shall provide a useable picture at a minimum illumination of 0.02 Lux. The weighted signal to noise (SN) ratio shall be greater than 50 dB at 1.0 V p-p, 75 ohms. The Cameras shall have MTBF (Mean time between failures) of at least 50,000 hours of operation.

7.31.5 Digital Video Recorder (DVR)

The Digital recorder shall be stand alone and have the facility to record images on the hard disk and also on external recording devices such as DVD, Hard Disk etc. The digital Video Recorder shall have enough data storage capacity to store video of 15 days from all the cameras and shall have interface to archive the data on to the DVD/Tape for back-up. The DVR shall have sufficient video signal inputs to cater for all cameras. It shall have Capability alarm/event based recording and the facility for high speed searching based on inputs such as date, time, etc. The Digital recorder shall have functionality to display multiple video images simultaneously on a single Monitor/Screen.

7.31.6 Lane Controller

General

The Lane Controller shall be provided to control and monitor all the sub systems of the toll lane. It shall consist of CPU and power supply, Data Communication ports, Digital I/O port, Circuit breakers, Terminal blocks, Relays LAN port, IP 65 enclosure with high security locking mechanism. All the peripheral devices in the lane shall be hardwired to the Lane Controller.

Technical requirements

The system shall be modular with Input/output Card having adequate channels catering to interfacing of all the peripherals devices with a provision for adding extra two devices. The system shall be housed in a metallic enclosure and installed inside the toll booth. All the peripheral devices in the lane shall be hardwired to the Lane Controller.

7.31.7 User's Fare Display Unit

General

The Fare Display Unit shall be in the form of a variable message sign, controlled automatically by the lane computer, to indicate the category of the vehicle and the amount payable by the road user. The system shall be LED based. It shall be installed outside the booth, near the payment window so that the road user will have clear view of the fare payable.

Technical requirements

a)	Power Supply	:	220V/50 Hz AC
b)	Communication	:	RS232
c)	Operating Temperature	:	-10°C to + 55°C
d)	Protection	:	IP 65
e)	LED Reliability	:	100,000 hrs

7.31.8 Traffic Light System

General

LED based light signal, installed at the toll lane towards the exit side shall be connected to the lane controller. The traffic sign glowing red would indicate that the motorist has to stop and pay the user fee. After successful transactions, the traffic sign would turn green to indicate that the motorist can proceed onwards. Traffic lights shall be installed on a pole of about 2 m above the road surface on the right side of each lane. The Contractor shall decide the appropriate height taking into account other equipment to ensure clear/unobstructed

visibility and control through lane controller. The system shall work in synchronization with the boom barrier and shall have in-built night dimming function.

Technical requirements

a)	Size of the display	Approx. 200 mm diameter with sun visor
b)	LED	Industry standard, Red and Green
c)	Housing	Corrosion resistant material
d)	Environmental protection	IP 65
e)	Intensity	Day light visibility > 1000 mcd for Red, >1600 mcd for Green
f)	Operating temperature	-10 ⁰ C to + 65 ⁰ C

7.31.9 Lane Communication System

Voice communication installed in the toll booths shall provide “hands free” two-way verbal communication between the supervision staff in the toll control room and the toll collectors. The toll collector shall be able to attract the attention of the Supervisor in the control room by pressing a single button on the intercom slave unit in the toll booth. The equipment shall also have the facility to allow the supervision staff to monitor communication in the toll booth between the toll collector and the user or between any of the tollbooths without alerting the toll collector. The voice communication system shall operate independently of the Lane Computer system. It shall also be implemented in various rooms of the plaza building and at building access points. Two-way communications shall be possible as soon as the Supervisor responds by selecting the appropriate lane button on the Master Communication unit. One-way communication shall be possible from the Control Room intercom to all lanes simultaneously (broadcast).

7.31.10 Overhead Lane Signs (OHLS)

The overhead lane signs OHLS shall be mounted on the leading edge of the canopy covering the toll lanes above the center of the lane to indicate to the User whether the toll lane is open or closed for the processing of vehicles. A Red Cross signal would indicate that the lane is closed, whilst a green arrow would indicate that the lane is open to traffic.

Technical requirements

The OHLS shall be made of green and red LEDs. Signs shall be sufficiently bright and directed to indicate to a motorist approaching the toll plaza, at a distance of 250 m on a bright cloud free day that lanes are available for use. The cross and arrow aspects shall be larger than 300 mm. The sign shall be fitted with a sun-hood to screen the effect of the sunlight. The enclosure of the OHLS shall be constructed from a corrosion resistant

material. The enclosure shall have an IP 65 rating and be ventilated to dissipate internal heat. The system shall have night dimming function.

UPS System

UPS system shall be supplied for individual lanes and plaza systems separately. Each UPS system shall be designed for 125 percent of the total connected load. The power supply to all electronic equipment (indoor and outdoor) shall be fed from UPS which shall have minimum 2 hours backup. The power budget calculation is to be submitted to the Engineer.

Violation Alarm

The siren operates in conjunction with a violation and acts as a warning device. The purpose of the siren is to alert the plaza staff of a run-through through the lane. Visual indication is via a strobe light. It shall meet the following requirements:

i)	Technology	Motor driven
ii)	Audible rating	112 dB at 1 m
iii)	Hearing distance	500 m
iv)	Environmental Protection	IP 65

Computer Hardware

Plaza server shall have following minimum Specification:

- a) Intel Xeon 3.0 GHz or higher with Intel EM64T/1 MB Cache/ 800 MHzFSB
- b) 2 GB ECC DDR2 RAM upgradeable to 12 GB
- c) Dual Channel U320 SCSI Controller
- d) 6x36 GB (10K rpm) HDD, Hot-pluggable, with RAID-5 Support
- e) CDRW – DVD Combo Drive
- f) Dual Gigabit 10/100/1000 Ethernet
- g) Redundant Power Supplies, Redundant Fans
- h) Anti-virus pre-loaded
- i) Server Management Software – with remote management features onboard
- j) 20/40 GB DAT Drive
- k) Certifications: ACP V1.0 B Compliant PCI 2.2 Compliant, PXE Support, WOL support, Microsoft Windows 2000/2003, Linux, PCI-X1.0 Compliant
- l) Operating Conditions: Operating Temperature Range: 0°C-50°C
- m) Relative Humidity: 20 percent - 90 percent, non-condensing
- n) AC Voltage : 207V AC to 253V AC @ 47-63Hz

Bar code reader

The bar code reader shall be used to scan unique identification bar codes imprinted on media such as paper and plastic medium such as smart cards etc. The bar code reader shall

be equipped with easily visible LEDs and audible beeps that indicate the scanner's operation status. The barcode reader shall have a rugged protective boot with an adjustable stand and be mounted to a countertop or be left free standing for handheld scanning. The barcode readers shall conform to IS: 14700: Part 6: Sec 3; 2002. The bar code reader shall be IP54 protected.

Receipt printer

The receipt printer shall be a compact thermal printer able to print, as a minimum, toll payment receipts (text and graphics) and barcodes. The receipt printer shall use thermal fixed head technology. The print speed shall not be less than 150 mm/s for both text and graphic and at a minimum resolution of 203 dpi (8 dots per mm). It shall be able to support paper thickness of 75 - 80 GSM. The receipt printer shall support programmable English and Hindi fonts and graphics, including Barcodes of at least Code 128 format. The receipt printer shall have an automatic cutter with a self-sharpening ceramic rotary knife. The receipt printer shall be robust for use in a toll booth environment where there is heavy usage and possible dust and exhaust from vehicles. The auto cutter shall have a reliability of at least 1.5 million cuts. The receipt printer head shall have a Mean Cycle between Failure (MCBF) of at least 50 million print lines. The receipt printer shall have a Mean Time between Failure (MTBF) of at least 360,000 hours. The receipt printer enclosure shall be IP54 rated.

7.31.11 Toll Management System (TMS)

The Toll Management System (TMS) shall be responsible for processing the data into information that will be used to verify toll transactions, provide toll collector control, cash-up and performance facilities, and shall include a host of management tools and reports for the effective administration of the toll operation. The TMS shall also assist in auditing the toll collection operation. It shall be a modular unit with the capability for various modules and functions to perform independently at different levels of the toll collection operation. The TMS shall have various customized reports to assist in managing the toll facility, and to provide management tools to assess toll revenues. The TMS shall have financial management and traffic analysis tools to assist the operator in planning operations. The Contractor/supplier shall ensure that security updates and latest service packs, "patches" are loaded. Industry standard operating systems shall be utilized and all user licenses shall be provided. The database shall be an industry standard database and shall be supplied with all the latest service packs and patches, including user licenses.

Payment

The payment shall be made for design, configuration, installation and commissioning the ATMS, as complete job on the identified stretch of highway, as per directions of the Engineer.

Pay Item	Description	Unit

7.31.1	Semi-Automatic Toll Collection System	On Completed Work

7.32 Advanced Traffic Management Systems (ATMS)

7.32.1 General

The work would cover design, supply, installation, commissioning and/or operation and maintenance of Advance Traffic Management Systems (which is one of the components of Intelligent Transport Systems - ITS). The system would include out-door equipment including emergency call boxes, variable message sign systems, meteorological data system, close circuit TV camera (CCTV) system, traffic counting and classification system and transmission system. The indoor equipment would comprise a large display board, central computer (with Network Management System - NMS), CCTV monitor system, call center system or management of emergency call boxes housed in a control center with uninterrupted power supply. Any new technology, meeting the requirements specified in these specifications should not be excluded. The systems shall meet following objectives

- a) Smooth and uninterrupted traffic flow
- b) Enhance road safety
- c) Real time information and guidance to users
- d) Emergency assistance round the clock
- e) Alerts for abnormal road and weather conditions
- f) Reduced journey time and inconvenience
- g) ATMS shall provide online recording and reviewing of the voice & visual information for record and analysis.

System Configuration

The ATMS shall have following sub-systems:

- a) Emergency Call Boxes
- b) Mobile Communication System
- c) Variable Message Signs system
- d) Meteorological Data System
- e) Automatic Traffic Counter cum Classifier System
- f) Video Surveillance System
- g) Video Incident Detection System (VIDS)

Availability Requirements

- a) make emergency calls to Control Centre in case of accidents, breakdown, fire and ambulance
- b) pre-warn the highway users about unusual condition on the road
- c) ATMS shall provide the following information/data to traffic managers for efficient and effective handling of traffic
- d) information regarding location of any incident, incoming calls, help required and messages to be passed to third parties
- e) Information regarding traffic congestion, speed and weather conditions
- f) ATMS shall provide the following controls to traffic managers
- g) change the variable message signs from the Control Centre
- h) Mobilize the movement of ambulances, cranes & patrolling vehicles.

The inability to perform any required function, the occurrence of unexpected action or degradation of performance below the specifications shall be considered as a failure. The Mean-time-between-failure (MTBF) shall be the average operating time accumulated by the total population of identical items between failures. The system supplier/contractor shall submit MTBF and MTTR figures. The ATMS shall have an overall system availability of better than 99 percent. The ATMS shall be considered unavailable if any of its function cannot be properly executed and when any of the following conditions persist for more than 8 hours on the entire stretch.

- a) **Variable Message System Failure:** No display/Improper Display of VMS or failure of their related transmission/control system which would render the VMS inoperative
- b) **Emergency Call System Failure:** Failure of any three consecutive Call boxes or failure of their related transmission system which would render the call boxes inoperative.
- c) **ATCC Failure:** Failure of more than one ATCC or failure of their related transmission system which would render the ATCC inoperative.
- d) **Met Failure:** Failure of more than one Met or failure of their related transmission system which would render the Met inoperative.
- e) **Video Surveillance System Failure:** Failure of more than two Video Cameras or failure of their related transmission/control system which would render the cameras inoperative.
- f) **Video Incident Detection System Failure:** Failure of more than one Video Cameras or failure of their related transmission/control system which would render the cameras inoperative.

- g) Display at Control Centre: Whenever Control Centre is unable to get display of messages initiated by the Control Centre in-charge.

In addition to the above the system shall be considered unavailable when failure of the integrated ATMS Software or its hardware persists for more than 8 hours.

Reliability Requirements

The supplier shall ensure that ATMS supplied shall comply with the following reliability requirements:

ATMS (Sub-Systems)	Mean Time Before Failure - MTBF
Outdoor Equipment	15,000 hours
Transmission System Equipment	15,000 hours
Control Centre Equipment	15,000 hours
Power Supply Equipment	15,000 hours

Maintainability Requirements

The Mean-Time-to-Repair (MTTR) of the ATMS to full normal operation following a failure shall be less than 8 hours all inclusive.

System Safety Requirements

The ATMS is classified as a safety related system and a minimum of CENELEC standards EN50128 software integrity level 2 shall apply. All equipment must comply with and be installed in accordance with IEC 65, IEC 364. All metal enclosures shall be provided with an earthing terminal and earthing of all equipment shall be carried out in accordance with overall earthing policy.

7.32.2 Environmental/Climatic Requirements

7.32.2.1	Indoor equipment :	
	Temperature (Operating)	0°C to + 50°C
	Relative Humidity	Up to 95% (non-condensing)
7.32.2.2	Outdoor Equipment	
	Temperature (Operating)	5°C to + 60°C
	Relative Humidity	Up to 95% (non-condensing)

The system and the equipment used as a minimum shall meet the following climatic and environmental requirements

Tests	Severities
Change of Temperature (Temp cycling)	Low Temp 0°C + 3°C
	High Temp 60°C + 2°C
	Rate of cooling and heating 1°C/m
	Duration of each cycle 3 hours
	No of Cycles : 3
Damp heat (Cyclic) test variant 1	Upper Temp 40°C + 2°C
	Lower Temp 25°C
	One Cycle 12 h
	Relative humidity 95 percent
	No. of Cycles : 6
Vibration (Sinusoidal) test	Freq. range 10 Hz – 55 Hz
	Vibration 0.35 mm
	Amplitude
	Duration of 20 sweep cycles endurance (10 Hz – 55 Hz) for sweep
	No of axes 3 co-ordinate axis
	Duration at 30 min+1 min resonant frequency

7.32.3 Emergency Call Box

The apparatus is a communication medium to be installed on the highway and to be used by the road users to make alarm call to the Control Centre in case of accidents and other emergency problems on the road or any incident. The Emergency Call Boxes shall be located in pairs on opposite sides of the highway. Main ECB unit (Master) shall be located on one side and the secondary unit (Slave) on the opposite side.

System Configuration

The Emergency phone shall comprise loud speaker, microphone, activation button, ringing tone to indicate progress of call when button is pressed, confidence tone to indicate call is still connected when on hold, recorded message in case the line is busy and LED indication during conversation. These components shall be provided in FRP (Fibre Reinforcement Plastic)/stainless steel/Aluminium Alloy housing.

General requirements

The ECB shall be designed for hands free operation. It shall be identified by reflective guide sign placed approx. 10 m ahead of the ECB. It shall have a provision for mounting on a concrete base with cast-in bolts, nuts and washers and the whole shall be installed so as

the persons using the instrument will normally be facing the oncoming traffic. The enclosure shall be equipped with retro reflective sticker that is clearly visible at night. The sticker shall read 'SOS' along with a telephone symbol. It shall have provision for the instructions of operation to be written clearly on the outside surface in two languages. Voice Logger Software shall be provided to handle and log all calls from the network. There shall be up to four programmable auto dial numbers associated with the push button. The ECB shall automatically dial subsequent numbers if the first number is busy or unavailable.

Technical requirements

The ECBs shall work on DC supply and operate in full duplex mode. It shall be able to operate in a noise level of up to 95 db. The ECB should be suitably protected against external EMI/ESI interference through shielding or grounding. It shall have in-built programming port/ feature for addressing. The same must be capable of being addressed using Laptop or Palmtops in fields. The ECB Central software shall use this address for identification of ECB. The ECB shall use latest components and a micro controller of adequate capacity to meet the system requirements. It shall have in-built fault diagnostics features for on-site maintenance and have extant protection against lightning. It shall be powered from the communication cable/solar panel. The solar panel and battery shall be adequately rated to support the ECB working under idle conditions and a talk time of minimum 90 minutes over 3 days in succession under worst climatic conditions. At each location one ECB shall be Master and the other Slave. The master ECB shall be equipped with fibre optic interface, solar panel, battery back-up and voice communication mechanism and shall also comply with all the requirements specified in this section for ECBs. The slave ECB shall be equipped at least with

- activation button, vandal sensing mechanism, call progress indication LED, Microphone, Speakers, Handicapped operation activation – in a weather proof housing as detailed in these Specifications. The system shall detect vandalism and give audio-visual alarm at the control center. The ECB system shall have a product support guarantee of 10 years from the manufacturer. The ECB central system shall communicate with the Central Traffic Management System and all the events and alarms shall also be displayed and stored in the Central Traffic Management server.

The ECBs shall meet the specification as per the following:

- a) Electromagnetic compatibility: be suitably protected against external EMI/ESI Interface through shielding/grounding.
- b) Lightning Protection: to be suitably protected.
- c) Drop and topple: BS2011 or equivalent.
- d) Enclosure: IP 65.

The equipment shall conform to all applicable electrical standards in India.

7.32.4 Mobile Radio Communication System

General

The mobile communication system shall be provided to establish voice communication on radio between the Control Centre and the emergency mobile vehicles such as ambulances, cranes and patrolling vehicles. The system shall comprise base station unit, repeater unit, mobile radio unit and control center equipment. Its Base Station Unit shall comprise transmitter, receiver antenna switch, radio engineering terminal, radio data terminal, radio operator terminal and power supply. Its Repeater Unit shall comprise transmitter, receiver, antenna, repeater and power supply. Its Mobile Radio Unit shall comprise transmitter, receiver, antenna, control unit and power supply. The Control Centre Equipment shall have Network Management System.

General requirements

The system shall cover the entire route. The system design shall be modular in concept. The system shall be compact and rugged in design having ease of maintenance and shall work satisfactorily under adverse conditions like storm, rain and vandalism resistant. The system shall neither affect functioning of other telecom equipment installed adjacent or along it, nor get affected by the presence of other equipment/systems. The Mobile Radio shall have provision for mounting the mobile set on ambulances, cranes and patrolling vehicles. The repeater station equipment and antenna shall be installed at sub centers. Each mobile unit shall have a unique address code. The system equipment shall work on rechargeable batteries with 24 hr back-up.

The control panel of mobile unit and base station unit shall have the following features:

- a) Power ON-OFF switch
- b) Emergency calling button
- c) Adjustment of loudspeaker volume
- d) Digital display
- e) Functional buttons

Functional requirements

The modulation shall be either frequency or phase type (FSK) and shall operate in semi-duplex mode. The equipment shall have provision to eliminate collision of data. It shall have facility to configure the network for individual, sub-group or broadcast mode of operation for both selective calling and group calling operation. All components used in the assembly of equipment shall be of industrial grade specification. The equipment shall conform to ETS European standards and shall be suitably protected through shielding/grounding against external EMI/ESI Interference, and shall be immune to RFI, ESD and lightning.

Technical requirements

The system shall have the facility to connect mobile to mobile, mobile to controller and controller to mobile. The system shall have the facilities for waiting calls, holds calls and transfer calls. The system shall have a facility such that the Control Centre can select between the call modes of individual call, group/all-call and call to mobiles listed in the queue. The system shall use primary channels for calling from mobiles to the Control Centre and vice-versa whereas the secondary channels shall be used for mobile to mobile connection. The system shall have the facility to terminate the mobile to mobile connection under the following conditions:

- a) One of the two parties hangs up
- b) One of the two parties receives a call from the Control Centre
- c) The duration of the conversation exceeds 5 minutes limit.

In case of emergency, the system shall have the facility to receive alarm calls from mobile radio. The mobile radio shall be integrated with the Fibre Optic Communication system. The system shall use frequencies to be obtained by the contractor from WPC in the complete stretch as per scope. The system shall have the provision for communication on the PSTN Network. The system shall have suitable voting system to select the better signal at base stations as well as mobile units. The system shall have provision to handle calls from/to at least 20 mobile sets. The system shall have self-diagnostic features. The system shall be protected against any damage due to power supply fluctuations, transients and surges.

7.32.5 Variable Message Signs

VMS Solution is a fully automated solution that provides real time, contextual updates to motorists in an automated fashion without the need for any manual intervention.

This solution helps increase Road Safety & enhances Road User Experience. A Smart VMS seamlessly integrates with a host of IOT (Internet of Things) nodes thereby enabling a host of applications such as Weather, Parking, Air Quality Monitoring, Disaster Management, Vehicle Monitoring & counting, etc. The solution is powered by 3M's Analytics Engine which is designed to provide automated traffic & congestion updates & predictive analytics to road users in real time thereby helping reduce congestion.

Key Features:

- a) Provides Real Time, Contextual & Useful Updates to Road users in an automated fashion

- b) Integrates with a host of third party sensors to allow applications such as Parking, Air Quality Monitoring, Weather, etc
- c) Instant citizen communication tool for disaster management.
- d) Highly secure solution providing you best in class security & encryption
- e) Robust solution that works seamlessly even in the event of control room failure.
- f) In built Analytics Engine provides powerful traffic and congestion analytics

Function

The Variable Message Signs (VMSs) shall provide to road users the advance en-route traveler information of road conditions ahead in real time. VMS shall generally provide:

- a) Advance information on incidents such as accidents, traffic diversions, incident management and notice for road work, adverse weather and road conditions and operation with lane control signals;
- b) Traveler information such as display of road construction activity in near future, messages for testing of the system and special events that affect the traffic flow;
- c) Public service announcements like messages relating to driver safety campaign.

Fixed VMS

Fixed VMS shall be mounted on a sturdy and aesthetically pleasing gantry structure whereby the vertical clearance of at least 5.5 m is available from the road. Safety barriers shall be provided at gantry support column(s) for their protection and for safety of road users. The concrete pedestal for support column should be flushed with ground but in no case should protrude for more than 1.5 m.

The minimum distance of VMS on expressways should be 1.5 km prior to decision point and that for National Highways it should be 1 km. The signs should be visible from a distance of 250 m. It should not be located on a curve and on a highway sections having grade exceeding 4 percent.

There should be clear distance between existing sign and VMS. The minimum distance between road signs and VMS should be at least 250 m on expressways and 150 m on National Highways.

Portable VMS

Portable signs can be mounted at the back of the truck or similar vehicle. The portable VMS signs mounted on a truck could be powered by solar energy or battery and show the sign of 'men at work' and/or speed limits in the construction zone. They shall be so placed that they are effective. The placement must give adequate time to the motorists to react to the message and take corrective action. On Expressways and National Highways placement of these at 2 km prior to the decision points should be done with repetition at every 500 m. It should provide a sight distance of 300 m and should not interfere with other traffic control devices. If the portable VMS set-up and a message are not to be required for a period of next four hours or more, the sign panel should be turned away from the traffic, parallel to the road center line. Non blank signs should be facing the drivers for an extended period.

Under no circumstances shall VMS be used for advertising of any kind. It would be in blank mode when traffic, roadway, environment or pavement conditions or public service announcements do not warrant the display of message or messages.

Type of messages through VMS

The average driver or motorized vehicle at high speed can comprehend two message panels. Each panel should be complete phrase and each phrase should be independent of the other. The messages should consist of:

Type of Statement	Example
A problem statement	Road work/accident ahead
An effect statement	Delay/congestion
An attention statement for certain group	Motorist
An action statement	Take the next carriageway

Some typical messages are as given below:

Accident Ahead, Road Closed, Take Diversion;

'Accident Ahead' followed by some typical messages like 'Expect Delays', Merge Right', Merge Left', 'All Traffic Exit' can be displayed.

Maximum Speed:—————kmph

Speed Limit strictly enforced;

Construction Work, Road Closed; Signal Ahead; Sharp Curve Ahead; Congestion Ahead;

Bad weather conditions like ‘Heavy Fog Ahead’, ‘Poor Visibility Ahead’;
Trucks use Left Lane; Watch for Stopped Traffic; Watch your speed; Watch for Falling Rocks: (In the case of landslide prone areas);

Two Way Traffic Ahead (this message can be displayed where the road section abruptly changes from four/six lane divided section to two lane bi-directional carriageways);

No Mobile When Driving; Drunken Driving Prohibited;

Technical requirements

The design of the system shall be modular. The system shall use LEDs/high gain Trans reflective LCDs for outdoor full sunlight. The failure of one LED module should not affect the output of any other LED cluster. Its design shall be such that the display is legible from a distance of 300 m on Expressways and from 250 m on other highways.

The equipment will comply with the following:

a)	Overall Size Board	Length minimum 3000 mm Height minimum 1800 mm Depth 200 mm
b)	Number of Display Lines	3
c)	Number of Characters per line	15
d)	Height of Characters	minimum 400 mm
e)	Language	Bilingual
f)	Contrast Ratio	> 30:1 perpendicular to the board face >10:1 at an angle of + 70° to perpendicular.
g)	Memory	Capable of storing minimum 10 frames that can be triggered on receiving the tele-command.
h)	Housing or other	Powder coated housing with IP54 equivalent international standard for protection and easing against dust, sprayed water and winds.

i)	Mounting	Pole mounted as gantry or cantilever with vertical clearance of 5.5 m from the surface.
j)	Interface Standard	RS422 and RS485 interfaces with compatibility on Ethernet.
k)	Special Features	Automatic diagnostic and reporting of failure/ fault of arrays/ rows
l)	Additional Features and humidity sensor.	Incorporation of temperature sensor
m)	Luminous Intensity (LED)	3000 mcd
n)	Life of Components of VMS	> 10 years

Elaborate Fault diagnostics shall be provided as per EN 12966 or other equivalent international standards. Each pixel shall be monitored and feedback shall be provided for the health status. Minimum of following shall be provided:

- a) Power Failure at VMS
- b) Processor PCB Failure
- c) LED Cluster Failure
- d) Loss of incoming message/data not properly received.
- e) Temperature monitoring.

The controller unit shall provide brightness control facility. In order to monitor ambient temperature of the housing the controller shall be capable of automatically diagnosing and reporting component failure or any electronic fault. The controller shall be provided with a test port for local diagnostics via laptop. It shall be possible to perform fault diagnostics from the central control room via the software. The LED Clusters shall be mounted suitably for providing better viewing angle. Each display module shall have its own display interface to the Central processor. VMS shall be designed to comply with the following protocols:

NMCS2, MESSAGE CONTROL, TR2070D, NTCIP Version 2 or other equivalent international protocols.

Testing

The equipment shall be tested for functional requirements as below:

Messages shall be displayed using the central software and local terminal. The fault conditions shall be simulated. Messages/fault logs shall be checked for:

- a) LED FAULT
- b) Communication failure
- c) Power failure
- d) Brightness of Pixels

Installation requirements

The structure on which the VMS is mounted shall be sturdy and aesthetically looking and capable of bearing wind loads up to 200 kmph. The lowest hung part of the display board shall have vertical clearance of at least 5.5 m from the road level. It shall be provided with a walkway to allow at least six persons to carry out maintenance of the VMS without obstructing the carriageway.

Transmission System

General

The Transmission system provides connectivity between Control Centre and outdoor equipment such as Emergency Call Boxes, Variable Message Signs, Meteorological Data System, Video Cameras, Traffic Sensors, etc. The system shall comprise Cable System, Interface System and Optical Fibre Transmission System.

Cable system

The system shall comprise copper cable, Backbone Optical fibre cable (for connectivity between the sub-centers and main control centre) and auxiliary fibre optic cable for connectivity of the road side equipment to the sub-centre and Coaxial cable. The cable system along with interface equipment shall work satisfactorily under adverse conditions like storm, etc. The Optical Fibre Cable system shall interconnect with the defined optical transmission sources and also if required with associated network devices for signal transmission without any impairment. A separate and independent (auxiliary) Optical Fibre Cable system shall be used for the transmission of video signals; data signals from the equipment locations to the sub-centers where copper cable has limitations for transmission of signal

All Optical Fibre Cable shall be of TEC (Govt. of India) approved design.

The Co-axial Cable System shall provide immediate interface to carry signals from CCTV /VIDS Cameras located at strategic locations to the nearest sub center. Optical Fibre Cable shall also be used with transmitters and receivers if the distance is large and high quality signal transmission and reception is not possible using co-axial system. The signals shall, without any impairment, be routed to the Control Centre via the sub-centers using the auxiliary Optical Fibre cable.

Interface system

Interface System shall comprise Sensor interface equipment, Optical fibre cable interface equipment and Control Centre interface equipment The Interface System shall cover the

Copper Cable, Co-axial Cable and Optical Fibre Cable System and transmit and process the composite signals to achieve the desired reliability/availability requirement. The Interface sub-systems shall be capable of handling the composite audio, video and data signals at various interface levels and process them. The Interface sub-systems shall be designed optimally at various levels i.e. from the individual sub-systems level to integrator through Control Centre.

OFC transmission system

The system shall comprise optical line terminals, interface cards and network management. The Backbone Optical Fibre Cable System shall interconnect the sub-centre/integrators and the Control Centre. The Optical Fibre Cable system shall interconnect with the defined optical transmission sources and also if required with associated network devices for signal transmission without any impairment. The backbone communication of Cable system shall be used only to interconnect the sub-centers to the main control centre. This cable shall be terminated only at the sub-centres and main control centre. It shall not be allowed to interface any other sub-systems in the field to this cable or any spare cores in the cable directly or through branching. A separate and independent (auxiliary) Optical Fibre Cable system shall be used for the transmission of video signals; data signals from the equipment locations to the sub-centers where copper cable has limitations for transmission of signals. This would be finalized during approval of detailed design by the successful bidder.

Power supply system

The Power Supply System shall support the requirements of individual sub-systems. The Power Supply System proposed for individual sub-systems shall take into account the overall availability/reliability requirements. The Power Supply System design shall take into consideration local power availability, temperature and other climatic variations, and easy maintainability.

Meteorological Data System

General

The Meteorological Data System shall consist of wind sensors for monitoring wind speed and direction, visibility sensors for detection of visibility changes resulting from fog or dust storm, atmospheric sensors to measure air temperature and humidity and road condition sensor to read road surface temperature. The system configuration shall therefore comprise thermocouple/dynamometer, humidity meter, anemometer and visibility meter.

Technical requirements

The Meteorological Data System shall communicate the measurement to the Control Center. It shall be compact, rugged in design and having ease of maintenance and shall be capable of detecting and keeping track of the surface temperature of the Highway surface and initiate appropriate alarms at the Control Centre.

The Sensor shall meet following requirements

Relative Humidity Sensor

Range	: -100%
Minimum Accuracy	: $\pm 2\%$ RH
Resolution	: 0.1%
Temperature Range	: -5°C to +60°C
Sensor Mechanism	: The sensor shall be adequately protected against dust/pollution and shall provide a linear output voltage for 0 – 100% humidity

Air Temperature Sensor

Range	: - 30°C to +70°C
Sensing Element	: should provide a linear output for the entire range of temperature
Resolution	: 0.1% of range
Accuracy	: $\pm 0.3\%$ of range
Visibility Sensor Range	: 50 to 1500 m
Wavelength	: 880nm
Sensor Type	: Infrared sensor, source and detector
Accuracy	: $\pm 15\%$

Wind Direction Sensor

Threshold Speed	: Less than 0.3 m/s
Accuracy	: Better than $\pm 5\%$
Damping ratio	: 0.7

Wind Seed Sensor

Range	: Up to 79 m/s
Threshold Speed	: Less than 0.3 m/s
Accuracy	: $\pm 2\%$
Output Signals	: Average Wind / Average Gust

Road Condition Sensor

Temperature Sensor	
Range	: -10°C to +60°C
Resolution	: 0.1°C
Accuracy	: $\pm 0.2^\circ\text{C}$

Wet/Dry Sensor

Output	: ON/OFF

Data acquisition controller:

The Data Acquisition Controller shall meet the following requirements;

- a) Be suitable for all the supplied sensors,
- b) Have appropriate number and type of inputs in order to service all the sensors,
- c) Incorporate an LCD display to allow local monitoring of the data,
- d) Have a memory backup (up to 7 days) to retain data locally in case of communication failure.

7.32.6 Automatic Traffic Counter cum Classifier

7.32.6.1 General

This system shall be provided for identifying and recording all types of vehicles on the highway for effective monitoring and data collection at Control Centre. Besides, the system shall be capable of classifying any other vehicle category as per user needs. Vehicle classification should be user selectable based on length of vehicle and/or detuning of the loop inductivity. The system shall be robust and be capable of operating with minimum maintenance. The system shall interface with the ATMS/ATMS Software for central monitoring. The indicative classification of common vehicles in India, based on wheel base, is as given hereafter.

Serial No	Types of Vehicle	Probable Range of Wheel Base (mm)
1)	Two Wheelers (Motorized) Scooters, Mopeds, Motor Cycle	0-1350
2)	Three Wheelers (Auto/Tempo)	1400-1800
3)	Four Wheelers Cars, jeeps, vans etc.	1801-2675
4)	Light Motor Vehicles	2690-3400
5)	Trucks/Buses	3401-5600
6)	Multi Axle Vehicles	5000-18000

Vehicle Classification should be user selectable based on length of vehicle and number of axles. The system shall have the capability of accommodating multiple installations through installation of detectors/sensors which can be left permanently in place and connected as required to the recording device when traffic counts are made at that particular location. It shall also be capable of taking inputs from portable sensors and should be modular in design. The system shall have capability of interfacing with the integrators for central monitoring. It shall have suitable interface for transmitting information from ATCC System to the Control Centre.

Technical requirements

Sensors: The sensors should be a combination of piezo-electric sensors and inductive loops, enabling counting/classification of up to 4-lane traffic (expandable to at least 6-lane traffic) with user set time periods.

Electronics: Vehicle counting/classification interval shall be programmable from one minute to 1440 minutes (24 hours) and system should accept user programmable recording intervals to count and classify during a 24 hour period. The system should be able to count and classify vehicle by each lane.

Data collection: The system shall be capable of sending data to the ATMS/ ATMS Software which shall enable the ATMS/ATMS Software to classify the vehicles, detect average speed per lane, vehicle occupancy and headway as a minimum. Data collection shall be by RS232, RS422 or RS485 interface or IP connection. The system shall be capable of recording, for later analysis, on an individual vehicle basis, time/date, speed, direction, number of axles, axle spacing and site identification.

Data storage: The system should be able to record and store vehicle data for a period of at least two weeks with daily traffic volumes of up to 10,000 vehicles.

Operating language: English

System accuracy: The accuracy of the system in recording speeds and headways/gaps shall as per Table 7.32-01

Table 7.32-01 System Accuracy Requirements

Parameter	Accuracy	Conditions
Average Speed	10 percent	There are at least 25 vehicles in the group, individual vehicle speeds are between 10 kmph and 195 kmph with vehicles conforming to normal highway driving behavior.
Average Headway	10 percent	There are at least 25 vehicles in the group, individual vehicle speeds are between 10 kmph and 195 kmph, individual vehicle head-ways are between 1 and 10 seconds and the vehicles conform to normal highway driving behavior.
Flows	5 percent	There are at least 100 vehicles of each category in group and vehicles conform to normal highway Driving behavior.

Occupancy	10 percent	There are at least 25 vehicles in the group, individual vehicle speeds are between 10kmph and 195kmph, individual vehicle headways are between 1 and 10 seconds and the vehicles conform to normal highway driving behavior.

Data retrieval: The system should have the capability of data retrieval, direct data transfer through a serial link to computer, Leased line/GSM/CDMA.

Software: Software and manuals to analyze the data from output of vehicle counts, classification speeds and headways shall be provided. Capability of graphic/tabular presentation of analyzed data shall also be offered.

Mode of operation: This will be user programmable up to at least 12 speed and 15 vehicle class bins, of vehicles operating in India (user specified). System capability in this regard may be indicated. Counter shall also bin simultaneously in speed, axle and count or any combination of the three.

Capability: The system shall have capability of recording vehicle counting and classification, speed, headway at set interval of 1-10 minutes.

Video Surveillance System

General

The System shall be provided to monitor the movement of vehicles on the highway. System configuration shall comprise video camera, video camera housing, pan and tilt heads, optical transmission units for video and data (if required) and mounting poles at camera locations. The Control centre configuration shall comprise monitors for individual cameras, matrix switcher, multiplexer and digital video recorder with suitable interface for the integrated highway package and optical interface units to the backbone communication system wherever required (where the video and data cannot be transported from camera location to the Sub-centre on co-axial cable). The Video Camera location shall be easily identifiable. The Video Camera shall be of dome type to avoid pilferage, be resistant to vandalism and weather-proof. The mounting and equipment housing shall be able to withstand adverse weather conditions and the Video Camera shall be capable of working satisfactorily under worst weather conditions. The Video Camera and associated units shall be water ingress and dust proof. The Video Camera mounting shall have easy accessibility for maintenance purposes.

Technical requirements

The Video Camera shall meet the following minimum technical as requirements:

- a) Image Sensor 1/4" CCD with 22 x optical zoom
- b) Active Pixels 752(H) x 582(V)
- c) Horizontal Resolution Minimum 470 lines
- d) Sensitivity 0.02 lux @ 1/1.5 Second shutter speed
- e) Focus Automatic (with manual override/preset facility)
- f) Signal to Noise >50 dB
- g) AGC Automatic with manual override
- h) White Balance Automatic with manual override
- i) Auto Shutter Yes
- j) Signal Format NTSC/PAL

The video camera shall have angular travel as below:

Horizontal: 360° continuous pan

Vertical Tilt: +2° to -92°

The Video Camera shall have speed as below:

Manual Speed

Pan : 1/10° to 80°/second (Variable)

Tilt : 1/10° to 40°/second (Variable)

Preset Speed

Pan : 250°/second

Tilt : 200°/second

The dome drive shall have 40 presets with labels and shall have an accuracy of +/-0.25° preset accuracy. It shall have built-in protection against Power Line Surge and Lightning and provision for Onscreen- compass and Tilt display, integral, auto sensing multi- protocol receiver/drive and provision for Auto-flip dome rotation. There shall be programmable limit stops for Auto/random/frame scan modes. The Video Camera shall be connected to the control centre/sub-centre through co-axial cable and data cable/optical fibre cable as per the site requirement and shall have remotely selectable operating modes and shall be operated from the Control Centre.

The video images from camera shall be transmitted in real time. The video image shall be made available at the control centre without any distortion or loss of information. The video camera system shall have the facility for zone blanking, auto identification of zones when the pan movement of camera is active and infra-red compatibility for night operation.

Video Incident Detection System

The system shall be an intelligent image detection system using CCTV cameras. The cameras shall have inbuilt intelligence to ascertain when the image has meaningfully deviated from the Standard Image originally recorded. On sensing the incident, the system shall automatically start recording the image at the control centre.

The Incident Detection system shall capable of the following:

- a) Measurement of traffic flow speed between 0 and 150 km/hr for up to 6-lanes
- b) Detection of vehicles driving in wrong direction
- c) Automatic detection of 5 types of traffic flow: normal, dense, delayed, congested, and stop and go
 - d) Detection of stopped vehicles, within 10 secs and for up to 16 detection zones.
 - e) Monitor Zone occupancy of the detection area
 - f) Detection of deceleration
 - g) Detection of fog/smoke

Alarms for following events:

- a) Queue
- b) Stop
- c) Inverse direction
- d) Speed drop
- e) Fog/smoke
- f) No video signal
- g) Error

Control Centre

General

The Control Centre shall accommodate following equipment and software:

- i) Central Computer Server (with integrated ATMS/ATMS Software)
- ii) Emergency call management system equipment and software
- iii) CCTV Console and other Equipment
- iv) Mobile radio operator and configuration equipment and software
- v) Video incident detection system console and other equipment

- vi) Backbone communication equipment and NMS for the same.
- vii) Large Display Board
- viii) Printer
- ix) Uninterrupted Power Supply with supply system and back up
- x) Power supply equipment.

Emergency call management

Emergency Call Management system located at the Control Centre shall carry out the following functions:

- a) Attend to incoming calls from ECB's using a PC based console, and navigate the highway section under supervision using graphical representation of the network which shall be displayed on the PC monitor.
- b) Provide audible and visual alert on the screen for any incoming calls from the Emergency call boxes. Color of the icon representing the Call boxes on the graphical map shall change indicating the states of call box (phone) healthy, call box (phone) faulty, incoming call, conversation in progress and call on hold.
- c) Provide for call waiting signal to the ECB and put the call on queue in case of several calls at the same time.
- d) Create log and record all conversations from and to the Control Centre from the ECBs.
- e) Further the system shall automatically check periodically (the interval of which shall be operator selectable) the health of phones and generate an audio visual alarm in case of faults.
- f) The system shall generate a unique call number for each and every call and allow the operator to provide annotation.
- g) There shall be one Emergency Call Manager's terminal easily expandable to more operator stations by connecting more operator terminals.
- h) Holding of any call by the operator.
- i) Terminating any call by the operator.
- j) Seamless configuration on addition/deletion of ECBs on the network.
- k) Database generation, display on the monitor and logging of all parameters of call progress.
- l) Recording of communication between the operator and road users.
- m) Audio visual alarm in case of vandalism.
- n) Audio visual alert in case of operation by handicapped.

Integrated ATMS software

The ATMS software shall manage the following on a single server platform:

- a) Emergency Communication System
- b) Variable Message Signs System
- c) Meteorological Data System
- d) Automatic Traffic Counter cum Classifier System
- e) Video Incident Detection System
- f) CCTV Surveillance System.

System architecture

Hardware for central server

The system shall run on a powerful dual-processor server with RAID facilities to provide continuity of hard disk storage. Storage capacity should be large; and comfortably sufficient to cater for the demands of a modern traffic management system. The system shall have client-server architecture so that multiple users may access the system simultaneously.

Minimum hardware specification shall be as follows:

- a) Server from reputed company
- b) Dual Core 2.2 GHz Processor or Higher
- c) Hard Disc : 5* 146 (RAID 5 Support)
- d) 4Gb RAM or higher
- e) Operating system : Industry standard
- f) The database : Industry standard
- g) Tape drive for backup/archive
- h) Facility for remote diagnosis and support.

Hardware for work stations/operator console

The workstations shall have the following specifications:

- a) Pentium IV 2.0 GHz
- b) 512 Mb RAM

c) 80GB ; Hard Drive

d) 19’’ TFT monitor

System software

The System software shall run on industry standard Server platform incorporating either MS Windows or Linux operating system in a client server mode. All the above subsystems shall be displayed and managed by the Supervisor which will show the status of all the above subsystems simultaneously as graphic symbols/icons. The graphic operator interface shall be menu driven for ease of operation. The operator shall be able to configure, set values, commands, perform database operations, reports, archive using these menus. The Integrated ATMS software shall monitor and record online all data from ATCC, Met Sensors, VMS, traffic control system, CCTV, VIDS and ECBs. It shall be possible to configure the sub-systems as well as add/delete components of the system such as ECB, VMS, MET sensor, ATCC, VIDS, and CCTV in the ATMS software online seamlessly.

The Integrated ATMS Software shall also have following features:

- i) The system server shall be configured so as to minimize the risk of data loss in the event of system failure or power loss. It shall support client terminals operating on a LAN, WAN or remote connection. Access to the database and client terminals shall be username and password controlled. Access level shall be determined by the system supervisor and shall range from “read only” to full edit/supervisor rights. The system shall not bypass/violate access rights setup on slave systems. It shall not be possible to send shut down or “Kill” commands from the database management system.
- ii) For system monitoring it shall be possible to configure a view only user with access to the map and embedded/linked data only. Such a terminal could be used by police, highway engineers, emergency services, etc. It shall be possible to relay urgent faults/incidents/System alarms (supervisor configurable) to remote operators/staff via an SMS message for any requirements in future.
- iii) The system shall have proven and modular Web interfaces. It should be possible to integrate the same if required in future for providing highway information such as CCTV images, traffic flow, journey time, etc., to the general public via internet web pages.

- iv) The system shall have proven and modular interfaces to automatic license plate recognition system. It shall be possible to integrate the same in future if required.

System functions

Sub-system monitoring and control

The System software shall monitor and control ATMS sub-systems as below:

- a) It shall monitor and record online all data from Meteorological Data System installed on the highway. The data shall be updated every five minutes.
- b) It shall monitor and record online all data from the ATCC. The system shall provide the user with the information/display of traffic flow conditions on the MAP. The data shall be updated every one minute.
- c) It shall monitor health of the Emergency telephones on a continuous basis.
- d) It shall monitor and control the variable message signs. The operator shall be able to generate new messages for signs. The system shall react intelligently and automatically to the highway conditions and set up suitable messages on the VMS. It shall also be possible to schedule the pre-defined messages to be displayed on the VMS. The display period shall be operator selectable. The priorities of the messages shall also be operator selectable.
- e) The System software shall provide information regarding incidents (VIDS) and store/archive them for future use.
- f) The system shall interface with intelligent traffic control systems for traffic control and monitoring specially at interchanges and access points.
- g) The system shall interface to CCTV system to select cameras for display and control of images.
- h) The system shall process above referred data acquired through above system for decision taking, display information on respective VDU monitors and central Large Display Board.
- i) Provide continuously clear and comprehensive displays and print log of events.
- j) Access to historical data files of ATMS.

- k) Execution of operator commands with access code security.
- l) Generation of reports at specified times (operator selectable)
- m) System timekeeping.
- n) Connectivity and data transfer to other control centers if required.

Graphic User Interface (GUI)

The GUI for the system shall be map based and menu driven. The changes commands/ menu shall be simple to be executed by the operator. There shall be a screen depicting the map of the highway along with other equipment installed on the route. The highway map shall be capable of displaying an overview level showing the whole area covered by the system. It shall then be possible with no loss of definition, to zoom to a detailed map. It shall be possible to display both static and dynamic data on the Map. Two level of mapping shall be supported as a minimum:

- a. Highway Overview.
- b. Highway section wise detailed view.

Icons shall be placed on the map to identify different equipment types. Both shall be automatically tagged with grid reference data to allow them to appear in the correct relative positions at both levels of map. Positioning the mouse pointer over an icon or poly-line shall display the corresponding equipment status information.

For poly-lines representing route data, the user shall be able to configure a number of thresholds for the different data types available. An example would be congestion for links where up to X% percentage thresholds can be defined. Each threshold shall be represented by a distinct Color or changed shapes. The map shall use this scheme to display the poly-lines based on comparisons with the current real-time data.

The user shall have the ability to configure the map view to display the data layers of choice, for example to show Met Sensor only or ATCC together with current incidents.

It shall be possible for the operator to place icons or “active” symbols on the map to represent

- a) Access control/ramp metering system
- b) Traffic control system
- c) Variable Message signs
- d) CCTV cameras

- e) Incidents such as Accident, Roadwork, Event, Diversion, Breakdown and Road closure
- f) Strategy
- g) Weather station data
- h) Flow, speed classification information
- i) User defined fields

Icons will be either active or non-active. Active icons will link to the associated system and show their current status change of state (Color or flash) and by displaying detailed information triggered user action.

Data base management

The database used by the ATMS software shall be an industry standard database like ORACLE, SQL, dbase etc. The system shall have facility to perform certain selected database operations only by authorized users.

Data presentation and storage

The presentation of data shall reflect the use of the system as a real time tool for the operator to monitor and control the highway. It shall be possible to present current data (day) in comparison with profile data or date comparison (same day last year). It shall be possible to create predictive traffic data and trends. The data shall be stored in the system in a format to present weekly and monthly average for congestion and summary flow for weeks and months. The system shall store at least 12 months of data. Older data may be archived. However, the system shall provide tools for the retrieval, manipulation and presentation of data. Data store shall be clearly marked with an indicator to show day or period type e.g. normal, holiday, weekly off; by reference to the system calendar. It shall be possible to export data to an external system for further analysis. Transfer shall be available in .xls, csv or any standard formats. It shall be possible to display data or combinations of data in graphical manner and to print graphs, e.g., Graphs of current, profile, historic, and combinations for

- a) Flow
- b) Occupancy
- c) Congestion

Archive and Restore

This facility shall allow the archiving of the database to a tape/External HD/DVD. The data archived shall then be deleted from the database. Data may only be archived when it is more than two years old. Only one archive request may be outstanding at a time. Once archived, part or all of the data may be restored by copying from the tape back onto the system, where it remains for 30 days. Only one restore request may be outstanding at a time.

It shall be possible to define a series of notification levels which will raise an alarm when the disk space reaches a specified limit. This is used to alert an operator to the need to archive data.

Database back-up

The system management procedures for producing daily and weekly back-ups shall not need any operator intervention.

Reports

The system shall have detailed reports for:

- a) Status reports for the sub-systems (alarms, faults etc.)
- b) Detailed traffic reports-speed, count, occupancy etc.
- c) Detailed weather report for all variables from weather sensor
- d) Detailed report of emergency call.

Timetable and calendar

The system shall have a time table facility. The timetable shall allow commands by day of the week, time of day, day type. The system calendar shall allow days to be marked as normal, holiday, weekly off, etc.

System log

The system shall retain a log of all events, alarms, timetable actions, and operator actions (together with operator username). In addition to system generated events the operators shall have facilities to enter events or incidents into the log. It shall be possible to search the log by time/date, event type, operator user name, strategy, location.

The log facility shall provide the means to:

- a) Record all important events that occur in the operation of the integrated highway management system, both manual and automatic View and manage the status of alarm events,
- b) Collect and collate incident information from both manual and automatic sources,
- c) Allow the user to record routine operational messages,
- d) View all changes and actions taken on the ATMS,
- e) Record and view useful contact names and other details.

Asset management

- a) The system shall incorporate a facility to store records of assets for ATMS.

- b) The asset register shall store data relating to location, type, and number of equipments as well as electricity ratings.

User management

This facility shall provide the means to make user access to ATMS secure. Only the system administrator(s) shall have access to this facility and will set up details for other users. Each user shall have a username that needs to be configured so that it matches a PC log-in. Hence logging on to the PC will automatically mean that access to ATMS is available for the chosen users. Each user can also be configured to have access to none, some or all of the ATMS facilities.

Operator interface and control

Fault and alarm management

Fault and Alarm Monitoring (FAM) for ATMS shall have following features:

- a) The FAM system shall be provided with the capabilities to monitor system alarm status on a real-time basis.
- b) The FAM system shall have the ability to store alarms in the database for future enquiries, and to access the fault alarm history database for retrieval of alarm data in the alarm history memory.
- c) All ATMS controlled equipment as well as VMS display boards shall be provided with fault monitoring and reporting to the FAM system.

Alarm handling

- a) The following alarm conditions shall be provided to the FAM system as a minimum:
 - Loss of communication link
 - Loss of the entire ATMS facilities at a location
 - Loss of interface link with the ECB
 - Alarm from MET Sensor-Air Temperature, Visibility, Humidity, Road Surface temperature, Road Surface wet/dry, Wind Speed, wind direction etc.
 - VMS Faults e.g. Communication Fault, LED Fault, Data parity fault, Power supply fault, Protocol polling fault to I/O Device, etc.

- ATCC faults e.g. Sensor fault, communication link failure etc.
 - CCTV faults
 - Traffic control system faults-Lamp LED Fault, Sensor fault, communication link failure, etc.
 - Power supply unit failure
 - Automatic Message priority conflict.
- b) All failure alarms shall be stamped with time and date.
- c) All failure alarms shall remain on the active alarm display list until they have been acknowledged by the operator on the FAM system via the management workstation.
- d) All alarms removed from the active alarm display list shall automatically be inserted into the alarm history database when they occur.
- e) The alarm history database shall be provided with sufficient storage capacity to store the anticipated alarms for a period of at least four weeks without carrying out any housekeeping function.

Alarm displays

- a) Alarms shall be displayed on the workstation via a detailed full screen alarm browser application.
- b) The alarm Display shall provide as a minimum the following general capabilities and characteristics for the ABA for alarm display list and alarm history:
- A Color-coding scheme indicating the alarm severity according to the alarm classifications.
 - The display of the alarms with their associated time stamps.
 - Scrolling capabilities to enable the operator to view more alarms that can be displayed on one single screen.

- The facilities to acknowledge alarms.
- The facilities to clear alarms from the display.

Fault diagnostics

The fault diagnostics system shall perform the following diagnostics features as a minimum.

- a. Detect the alarm conditions
- b. All fault status information and associated equipment test results shall be presented to the workstation immediately after the alarms are triggered.

Failure modes

When power is restored following a power failure to the system, the system shall perform all necessary self-testing processes and then resume functioning fully in the same configuration as before the shutdown. This shall be completed automatically within 5 minutes of power restoration.

Back bone communication system

The backbone communication system shall connect the sub-centers with the Control Centre. The auxiliary Optical Fibre communication system shall provide connectivity for peripheral systems like ATCC, CCTV, mobile radio, emergency call management system, VIDS, Traffic Control System, Mobile Radio and LAN interface for Tolling Systems to the Control Centre. There shall be a node for the backbone communication system at every sub-centre and the Control Centre. The network management system (NMS) shall be located at main Control Centre. It shall however be possible to connect the NMS at any sub-center location which houses a communication node. The NMS shall be installed on a PC.

Large display board Functions

- a) The device shall be used for monitoring the traffic through CCTV/ VIDS to display the ATMS Graphical User Interface (GUI). The large display board shall be displayed on the wall of the Control Centre. The Application software shall consist of a built-in module for display board.
- b) It shall be possible to create customized data acquisition screen and drag icons by simple click of the mouse.

- c) It shall be possible to create backgrounds using scanned photographs, maps, one-line diagrams, engineering drawings, etc, using popular graphic or engineering applications.
- d) It shall be possible to create new process diagrams that represent various sections of the highway at different levels of details using the package.

Equipment

The Large Display Board shall be highly reliable for installation and round the clock operation in the Control Centre. The Display Board shall be driven by the Central Computer using the main console. The design of the Display Board system shall be modular and expandable. The Display Board shall use high gain trans-reflective LCDs for ambient indoors. The Board shall meet the following specifications:

a)	Overall board size	Length minimum 3000 mm Height minimum 1200 mm
b)	Display	Graphic
c)	Contrast Ratio:	Minimum 1000:1
d)	Housing	Structure coated housing with IP54 Protection casing against dust, sprayed water
e)	Interface Standard	RS 422, RS 485 (Ethernet compatible)
f)	Special Features	Automatic diagnostics and failure reporting

Uninterrupted power supply Functions

The uninterrupted power supply shall be installed at the Control Centre for providing clean uninterrupted power supply to all the operational Equipment at the centre. The uninterrupted power supply shall be capable of providing full load for the operational equipment for a minimum period of 60 minutes. The Control Centre shall be powered from 230V AC from the State Electricity Board (SEB) supply. Any loss of AC power to the Control Centre from the SEB shall not cause loss of any data on the computers or any resetting of system parameters. The following requirements will be met:

Features	To meet the load requirement
Rating	230 V AC (+10% to -15%)
Input Voltage	50 HZ $\pm$ 10%
Input Frequency	High frequency switching sinusoidal multiple Pulse
Inverter Type	230 V
Output Voltage	Free running 50 Hz $\pm$ 0.1%
Output Frequency	

	Tracking bypass $\pm 2\%$
Output Voltage Waveform	Sinusoidal
Output Voltage Regulation	Better than $\pm 1\%$ for simultaneous variation of no. to full load and input Voltage to any extremes. $\pm$

Total harmonic distortion	<5%	
Inverter efficiency	>87%	
Transmit Response	for 100% step load	
	Dip-Typical 5% max. <8%	
	Peak-Typical 5% max. <8%	
	Recovery to normal up to 60 msec. i.e. 3 cycles.	
Overload capacity	125% for 10 msec.	
	800% on static bypass for 10 msec.	
Audible indication	<55 dBA at 1 meter distance for	
	i)	Mains OK
	ii)	Inverter OK
	iii)	Overload
	iv)	On battery
	v)	Low battery
	vi)	Inverter trip

Four extra LED indications shall be available with automatic bi-directional static switch for

- By pass OK
- Load on inverter
- Load on By Pass
- By Pass frequency out of range
- Metering for voltage, frequency and current
- Battery capacity required for minimum 1-hour back up at full load.

Warranty

The Contractor/Supplier of the Advanced Traffic Management Systems (ATMS) shall furnish the Warranty/Guarantee for successful commissioning and operation of ATMS for a

minimum period of 5 years. He shall also furnish the certificate that there is no proprietary item and that the Systems shall be interoperable. All components and equipment shall be tested for commissioning. The documents with regard to design, technical details, installation details, testing and commissioning, details of fault diagnostics, operation and maintenance manuals and reports shall be submitted to the Engineer by the Contractor/Supplier.

7.32.7. Payment

The payment shall be made for design, configuration, installation and commissioning the ATMS, as complete job on the identified stretch of highway, as per directions of the Engineer.

Pay Item	Description	Unit
7.32.1	Advanced Traffic Management Systems	on completed work





DIVISION 8

INCIDENTALS

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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 be 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

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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**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

