

Government of People's Republic of Bangladesh  
Ministry of Road Transport and Bridges  
Roads and Highways Department



# Bridge Rehabilitation and Strengthening Manual

**PART 1**

**Method** Final Draft

**August 2018**





## PREFACE

It is a matter of great pleasure that the **Bridge Rehabilitation and Strengthening Manual** has been developed by the consultants under the Bridge Management Capacity Development Project (BMCDP) of RHD with the cooperation of JICA.

**The Bridge Rehabilitation and Strengthening Manual 2018** is the updated version of the one titled "Major Repair Manual" produced by RHD in 2014. This manual is composed of "Part 1 Method" and "Part 2 Cost Estimate". In Part 1, in order to carry out the appropriate rehabilitation and strengthening of bridges, this manual covers how to select the rehabilitation and strengthening item regarding each defect of bridges and the rehabilitation and strengthening method. In Part 2, this manual covers to calculate the cost of rehabilitation and strengthening items.

This manual would serve as guidance on the fundamentals of bridge rehabilitation and strengthening and help the Bridge Management Wing of RHD to select the rehabilitation and strengthening item in bridge maintenance program. An intranet Bridge Management System (BMS) based on the new concept and functions for effective bridge maintenance management, is also developed under BMCDP as an integrated and accessible information system for the database of bridge inventory, inspection and maintenance work history.

Together with the systematic use of this BMS, this manual will be useful to the RHD field staff responsible for direct maintenance, the policy makers of RHD in this area and also the staff who will be involved in maintenance by contract.

We hope that this manual will assist in improving the understanding of the function of bridge structures and their long term durability and serviceability.

Finally, we would like to take this opportunity to thank the experts of JICA Consultant Team for their efforts in preparing the **Bridge Rehabilitation and Strengthening Manual 2018**.



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August 2018



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**Plate list for Routine Maintenance Works and Minor Repair Works**

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<b>Routine Maintenance Methods</b>		
Plate 1-1	Debris accumulation	Cleaning
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<b>Minor Repair Methods</b>		
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Plate 2-2	Damage of gabion wire mesh	Partial repair of gabion mesh
Plate 2-3	Spalling, Minor honey comb	Hand applied mortar
Plate 2-4	Minor corrosion of steel works	Touchup painting
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## Appendix 2 Plates for Major Repair Works

### Plate list for Major Repair Works

No	Type of defect	Element	Remedial Measure	Plate No
1	Crack on concrete	Concrete structures	Crack Injection	Plate 3-1
2			Crack Filling	Plate 3-2
3	Spalling/Exposed rebar Abnormal Anchorage	Concrete structures	Hand applied mortar (A) & (B)	Plate 3-3
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7	Fallen out of deck slab	Concrete deck slab	Partial Replacement of Deck slab	Plate 3-7
8	Crack on concrete Water leakage/ Efflorescence	Concrete deck slab	Carbon Fiber Sheet Bonding	Plate 3-8
9	Crack on concrete	Concrete girder	Carbon Fiber Sheet Bonding	Plate 3-9
10			Carbon Fiber Plate Bonding	Plate 3-10
11	Crack in Steel	Steel girder	Supplementing Steel plate	Plate 3-11
12		Steel Pier	Supplementing Steel plate	Plate 3-12
13	Spalling/Exposed rebar	Bored Pile	Filling Pile mortar/concrete	Plate 3-13
14	Scouring Abnormal spacing	Footing of Substructures	Footing consolidation	Plate 3-14
15	Water leakage/Puddle	Expansion Joint	Replacement of small move joint	Plate 3-15
16	Abnormal spacing		Replacement of steel joint	Plate 3-16
17	Water leakage/ Efflorescence	Concrete deck slab	Waterproofing-Asphalt compound type	Plate 3-17
18	Functional disorder bearing	Bearing	Repainting of steel bearing	Plate 3-18
19	Difference in level		Replacement of rubber bearing	Plate 3-19
20	Defect of reinforcing material	Concrete deck slab	Rebonding of strengthening plate	Plate 3-20



## 1 Overview

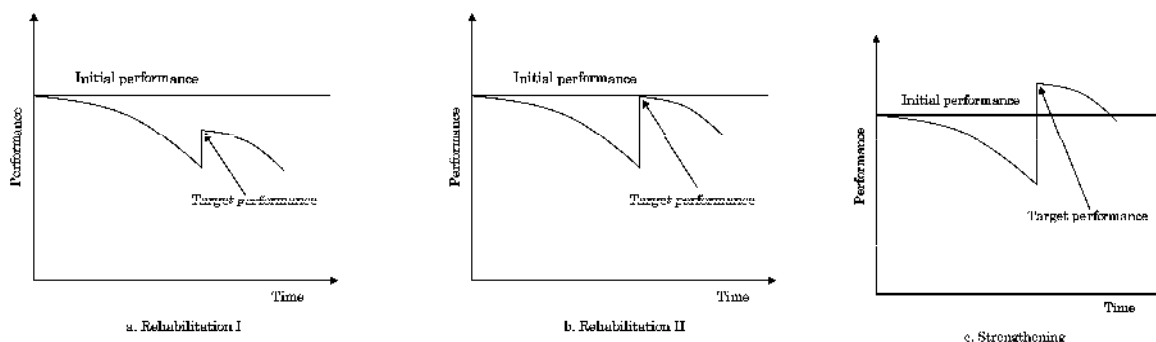
### 1.1 Scope of Application of the Manual

This *Bridge Rehabilitation/Strengthening Manual* includes rehabilitation and strengthening methods to cater to the defects commonly found in bridges and culverts owned and maintained by RHD, and is intended to serve as a *guide* for the rehabilitation works undertaken by RHD either through maintenance by the Department's own maintenance teams, or through maintenance by contract.

The manual is intended for use by

- (a) RHD's staff seeking guidance in selection of appropriate rehabilitation measures for bridges,
- (b) Implementation staff of RHD responsible for maintenance, or maintenance by contract,
- (c) Contractors of bridge rehabilitation works appointed for maintenance by contract.

The bridge rehabilitation methods suggested in this manual aim to maintain the bridge to bring back in sound condition and at its original design load capacity, while, the strengthening method means to increase load-carrying capacity by adding more material, additional components, and so on (Figure 1-1). In the Figure 1-1 are shown two types of Rehabilitation. Rehabilitation I is the cost saving method, to keep the current performance for e.g. 10 years, while Rehabilitation II is trying up to the initial (original) performance level.



**Figure 1-1 Concept of Rehabilitation and Strengthening**

Technical Special Specifications of relevant items including materials, equipment and workmanship have been covered along with methods of measurement and basis of payment.

## 1.2 Execution of Bridge Maintenance and Repair Work

Bridge maintenance and repair work are in general of specialized nature and shall be carried out in accordance with the drawings and specifications by well trained, skilled staff having the requisite experience, and shall be executed under the strict supervision of qualified technical staff well experienced in their specific trades.

Bridge maintenance works are divided into several categories as shown in Figure 1-2. Improvement is dealt separately from Maintenance Works. Detailed contents of bridge maintenance works are described in Bridge Maintenance Standard 2017, section 3.2. And, Bridge maintenance works are classified as in Figure 1-3 based on budget.

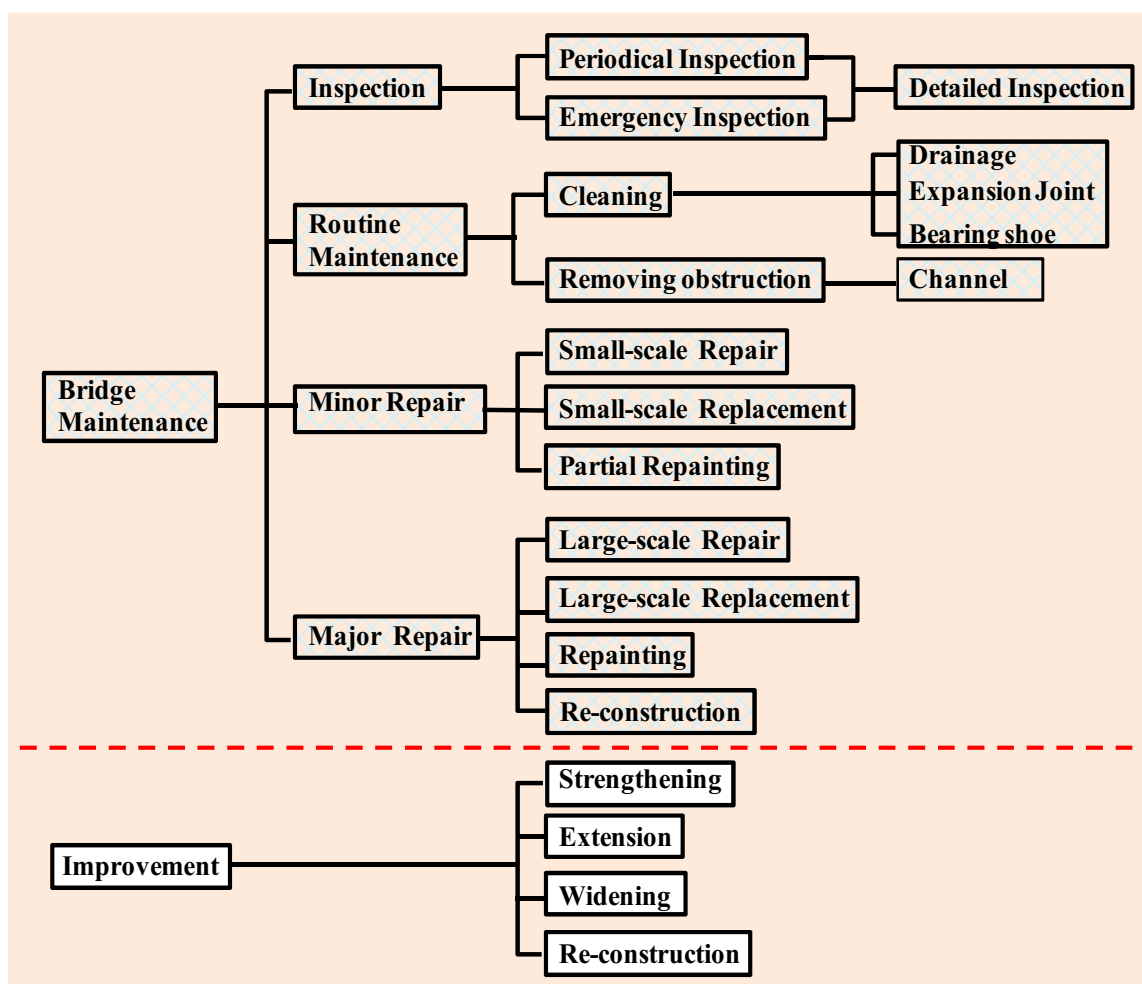
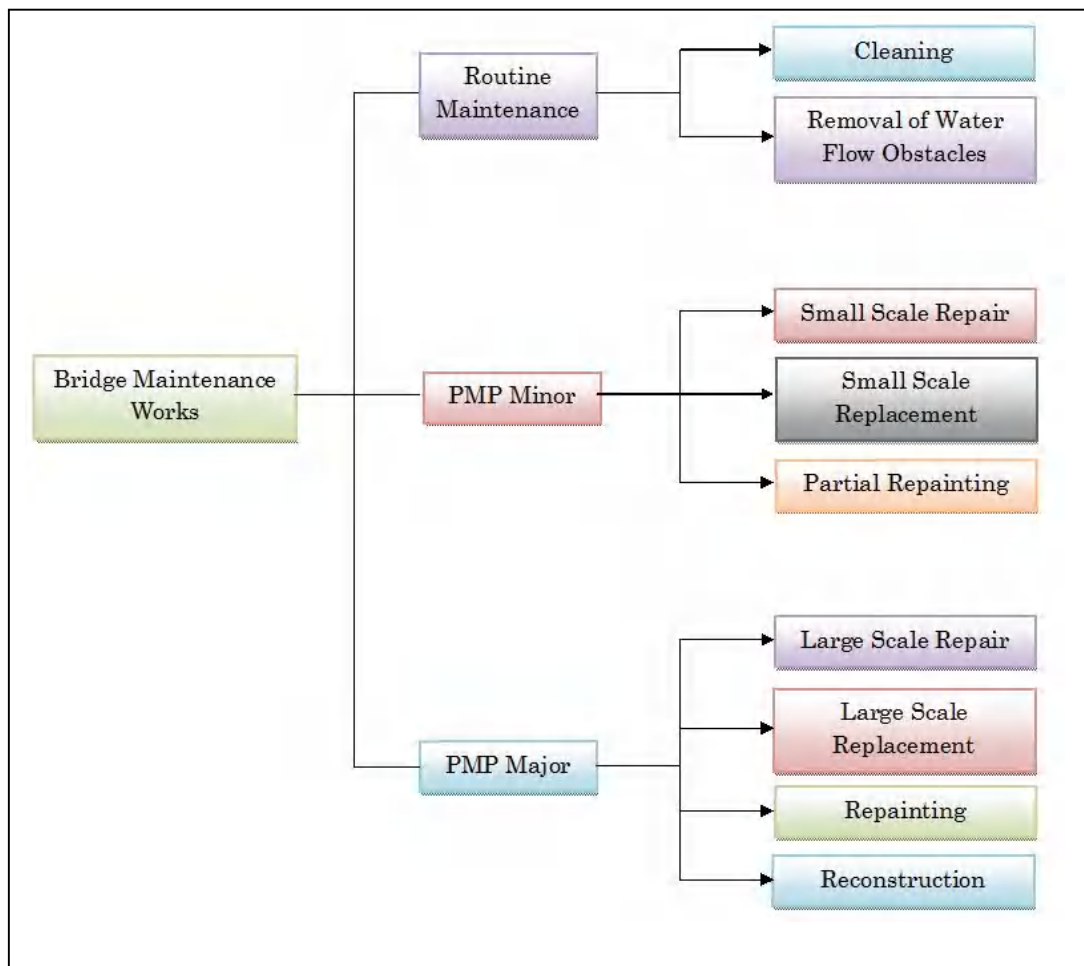


Figure 1-2 Categories of Bridge Maintenance Work

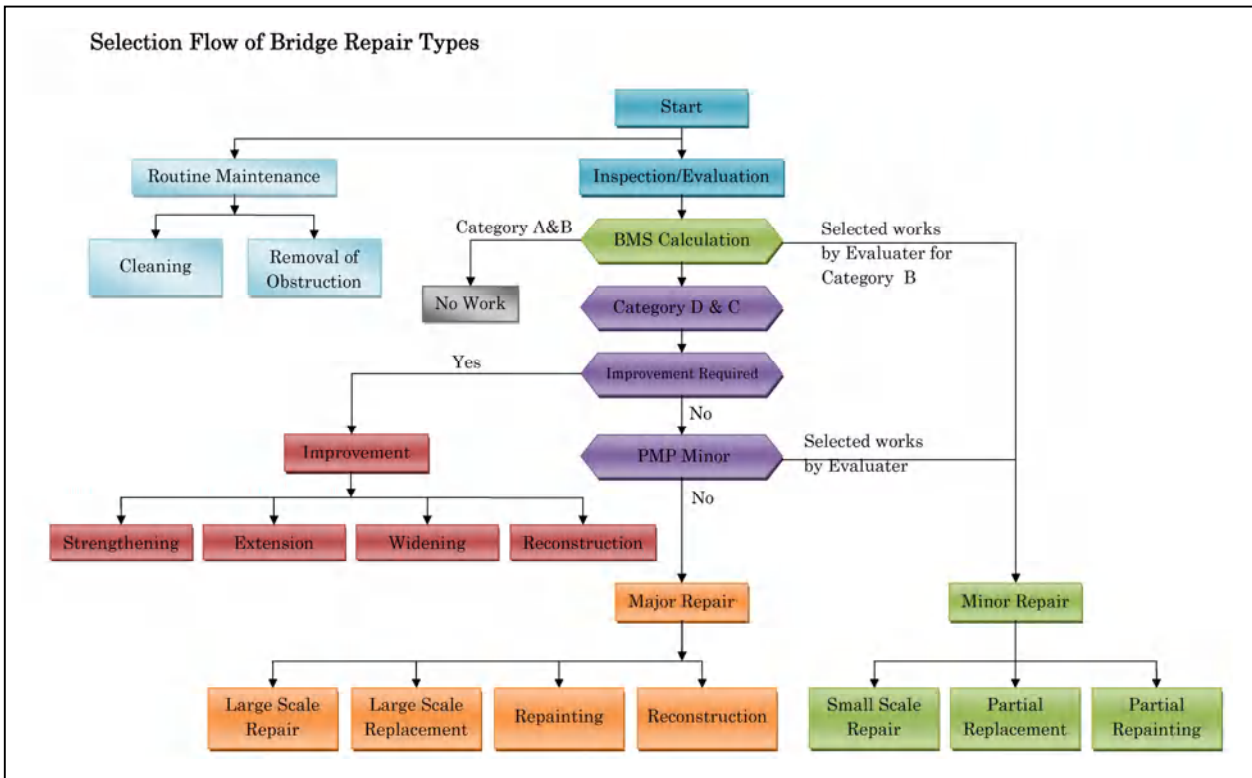
Routine Maintenance works are carried out to prevent the bridge from suffering further deterioration. Cleaning of bridge surface at curbs and railing, deck drainage system, expansion joint and bearing seat are low cost and most effective preventive maintenance for bridges. Also, removing water flow obstruction and weeds mowing are important routine maintenance work.

Minor Repair and Major Repair works are implemented to repair defects of a bridge and restore it to its original serviceability. Meanwhile, improvement works are implemented to upgrade the bridge serviceability with consideration of existing traffic condition, environmental condition etc.



PMP: Periodic maintenance program

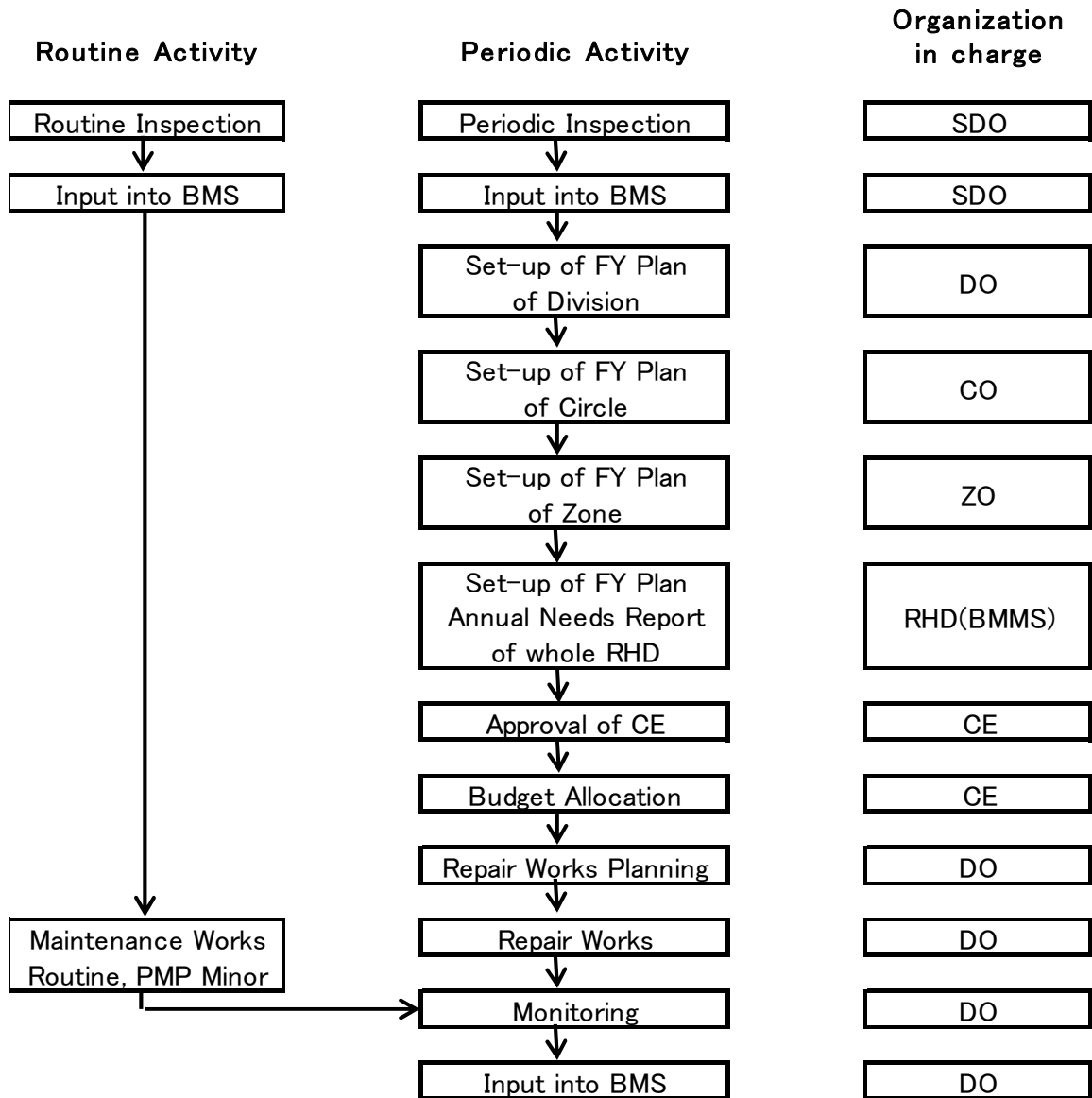
**Figure 1-3 Classification of Bridge Maintenance Works**



**Figure 1-4 Selection Flow of Bridge repair types**

Figure 1-4 shows Selection Flow of Bridge repair types. Minor repair works are selected by Evaluator, or in accordance with the section 3.2. The prioritization score of each bridge can be automatically calculated by inputting inspection/evaluation results into BMS. If giving budgetary limit in each year, the list of bridges to be repaired or to be replaced within short-term (five years) can be easily obtained.

The design and construction of any works shall be strictly governed by all statutory / regulatory requirements. It shall be ensured that all necessary approvals are in place before taking up any implementation activities.



NB) SDO: Sub-Division Office, DO: Division Office, CO: Circle Office, ZO: Zone Office  
 BMMS: BMMS Division, CE: Chief Engineer

PMP: Periodic maintenance program

**Figure 1-5 Flow of Short-Term Maintenance Plan**

## 2. Routine Maintenance Works

### 2.1 General

Bridge Maintenance Works are classified as Figure 1.2 based on budget.

Routine maintenance works and PMP (Periodic Maintenance Program) Minor maintenance works are categorized into preventive maintenance works and in many cases they are executed under the direct management of RHD. While, PMP major maintenance works and repair design are generally outsourced to private professional companies.

Routine Maintenance Works are the primary maintenance procedure. It should be done continuously in each Subdivision Office (SDO) by an organized team. The planning of Routine Maintenance works is done by SDE or SAE, covering every Routes and Regions in the SDO, so that every Bridges and Culverts are covered minimum twice in a year. If it is not possible to cover all Bridges and Culverts, the number of Routine Maintenance Works Team should be increased. It is very important maintenance action for preserve bridges in sound condition, under small budget. It consists of “Cleaning”, “Removal of Obstacles” and “Routine Repair”.

### 2.2 Cleaning

#### 2.2.1 Along the Curb or Felloe guard

Along the lower roadway curb or felloe guard, the soil, rubbish and weed are accumulated and cleaned.



Fig. 2-1 Removing of soil and weed by shovel    Fig.2-2 Removing of soil and weed by jet water

#### 2.2.2 Catch basin on the bridge and Drainage pipe

The soil and rubbish are often blocked up the Catch basin on the bridge and/or Drainage pipe. The blockage should be opened. Loose drainage pipe at joint is fastened or replaced.



Fig.2-3 Blocked catch basin at surface



Fig.2-4 Removing the soil by brush



Fig.2-5 Blocked drain pipe with bird's dung

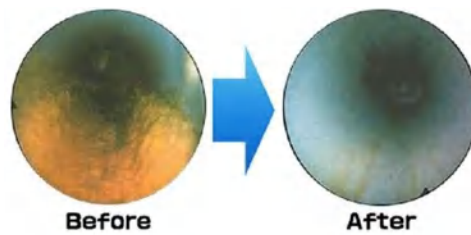


Fig.2-6 Pipe after jet water cleaning

### 2.2.3 Expansion joint and Bearing shoe

The opening of Expansion joint is blocked up by debris (soil, rubbish and weed). The debris is accumulated by hook/shovel and cleaned by water. Debris around the Bearing shoe and Shoe bed are accumulated and cleaned.



Fig.2-7 Blocked expansion joint



Fig.2-8 Cleaned expansion joint tube



Fig.2-9 Cleaning by female worker



Fig.2-10 Bearing with Debris



Fig.2-11 Cleaned Bearing by jet water

#### 2.2.4 Steel Girder and Concrete Girder at bridge end

Cleaning of steel/concrete girder at both bridge ends (each 5.00 meter) shall be done at regular intervals (1-2 times a year). It is very useful preventive maintenance action for bridge elements. At the coastal region, whole bridge (girders, deck slab and substructure) shall be cleaned also at same intervals.



Fig.2-12 Cleaned steel plate by jet water



Fig.2-13 Cleaning concrete surface by jet water

Remark; The ideal jet water pressure is, for example 15 MPa and Volume flow 15 liter/min.

If, business jet water cleaner is not available, so a household water cleaner with water pressure of 8 Mpa and Volume flow 5 liter/min also acceptable.

### 2.3 Removal of Obstruction

#### 2.3.1 Removal of Flow obstruction

At the routine maintenance work, Flow obstruction shall be removed by hook with long shaft. The Flow obstruction is often observed also at Box-culverts and Pipe-culverts.



Fig. 2-14 Pier with flow obstruction



Fig.2-15 Pier with flow obstruction



Fig. 2-16 Culvert with flow obstruction

### 2.3.2 Vegetation Growth

Under/around the bridge shall be the good airy place, otherwise bridge elements absorb moisture and bridge damage is speed up. Therefore, harmful plants shall be removed at regular intervals.



Fig.2-17 Harmful weed around the bridge



Fig. 2-18 Harmful weed under the bridge



Fig.2-19 Tree growth under the bridge



Fig.2-20 Mowing and Weeding under the bridge

## 2.4 Routine Repair

### 2.4.1 Loose and Missed Bolts

For Portable Steel Bridge (PSB) girder and steel deck, loose Bolts shall be fastened and missed Bolts shall be filled and fastened.



Fig.2-21 loose Bolts of PSB are fastened Fig.2-22 loose Bolts of steel deck are fastened

### 2.4.2 exposed Rebars

Exposed Rebars (small area) are treated by steel brush and painted with corrosion inhibitor by brush.



Fig.2-23 exposed Rebars (small area) Fig.2-24 Treatment of exposed rebar by brush

## 2.5 Organization

Routine Maintenance Works will be implemented by each Sub-Division Office (SDO) of RHD. The Routine Maintenance Works Team consists of a Team Leader (SAE), a Foreman and 2 Workers. Routine maintenance team led by SAE should work by the guidance/supervision of SDE and will report to SDE upon completing the job. SDE will report to EE about all the monthly work. The Team Leader should be trained Bridge Inspector and the Foreman is skilled Worker with good knowledge of Minor repair.

**Table 2.1 Typical organization of Routine Maintenance Team**

Position	Position	No. of Personnel
Team Leader	SAE	1
Foreman	Class III	1
Unskilled Worker	Class IV	2
Driver	Class IV	1

**2.6 Tools and Equipment**

The Routine Maintenance Team shall take following tools and equipment to sites.

**Table 2.2 Tools and Equipment**

Name of tools/equipment	Main Purpose	Team Leader	Number	
			Foreman	Worker
1.Handshovel	Removing debris	1	1	2
2.Shovel	ditto		1	2
3.Broom	ditto			2
4.Brush	ditto	1	1	2
5.Steel brush	Removing rust		1	2
6.Hook with long shaft	Removing obstructions		1	2
7.Hammer	Minor repair	1	1	2
8.Torque wrench	Tensioning Bolt-nut		1	2
9.Paint brush	Painting Steel		1	2
10.Water bucket	Transporting water			2
11.Cloth/Duster	Swiping work		1	2
12.Rope	Safety work		1	2
13.Expand ladder	Approaching to work place		1	
14.Generator	Power supplying		1	
15.Jet water cleaner	Removing debris		1	
16.Vehicle	Team and tool transport		1	

1.



2.



3.



4.



5.



6.



7.



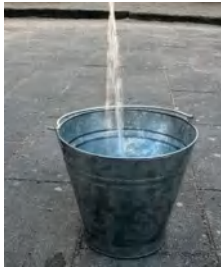
8.



9.



10.



11.



12.



13.



14.



15.



16.



### 2.7 Material

The Routine Maintenance Team shall take following material to sites for minor repair.

Usually there is no patching repair of concrete at the Routine Maintenance.

- |                            |  |
|----------------------------|--|
| Corrosion Inhibitor liquid | each Worker 1 can,                     |
| Bolt-Nut and washer set    | each Worker 10 set, different diameter |

### **3 Minor Repair Works**

#### **3.1 General**

Minor Repair Works is a part of Repair Works with relative small budget and will be implemented by each Division Office (DO) of RHD. However, it is recommended, that yearly budget for Repair works are divided into Major repair works, Minor repair works and Routine repair works. Therefore, Minor repair works are organized separately from other repair works.

The Minor repair works are included in many cases partly damaged bridge/culvert elements. Emergency cases such as traffic safety and public safety are taken priority even for Minor repair works.

#### **3.2 Typical Minor repair works**

Typical Minor Repair works for bridges are shown as follows:

a) Surface

Partial Pavement repair (Potholes or small Difference in Level at Expansion Joint)

Partial Curb/Sidewalk repair

Partial Railing repair/replacement

touch up painting

Partial Catch basin repair/replacement

Partial Drainage repair/replacement

Partial traffic Sign/Markings repair

b) Superstructure

Touch up painting of girder

Partial Replacement of Sub-Element

small Honey-Comb repair

small Spalling repair

c) Bearing

Touch up painting of steel element

small Spalling repair of Seat

d) Substructure

small Honey-Comb repair

small Spalling repair

Partial Backfill repair

Partial Stone masonry repair

Partial Gabion wire mesh repair

Typical Minor Repair Methods and Routine Maintenance Methods are shown in Table 3-1. Plate 1-1 to Plate 1-2 and Plate 2-1 to Plate 2-5 are attached in the Appendix 1 describing detailed method and procedure for each repair method.

**Table 3-1 Plate list**

<b>Plate name</b>	<b>Defect/Deficiency</b>	<b>Remedial Measure</b>
<b>Routine Maintenance Methods</b>		
Plate 1-1	Debris accumulation	Cleaning
Plate 1-2	Water flow obstruction	Removing obstructions
<b>Minor Repair Methods</b>		
Plate 2-1	Material loss from Stone and Mortar masonry	Repairing of stone masonry
Plate 2-2	Damage of gabion wire mesh	Partial repair of gabion mesh
Plate 2-3	Spalling, Minor honey comb	Hand applied mortar
Plate 2-4	Minor corrosion of steel works	Touchup painting
Plate 2-5	Abnormal bituminous pavement	Partial repair of pavement

### 3.3 Organization

Minor Repair Works will be implemented by each Sub-Division Office (SDO) of RHD. The Minor Repair Works Team consists of a Team Leader (SAE), a Foreman and 2 Workers (Table 3-2). The Minor Repair team will work under the supervision of SDE and will report to SDE upon completing the job. SDE will report to EE about all the monthly work.

The Team Leader should be trained Bridge Inspector and the Foreman is skilled Worker with good knowledge of Minor repair.

The Team leader arranges and schedules the Minor repair works in the SDO and he is responsible for Safety control and Quality control. If more skilled worker is preferable, the Team leader can arrange one or two more skilled or/and unskilled workers for that case.

The composition of the Minor repair team is similar to the Routine maintenance team; however the Foreman and Workers are not same persons desirably. While the Team leader takes concurrent duties on Routine maintenance and Minor repair Teams.

**Table 3-2 Typical organization of Minor Repair Team**

Position	Position	No. of Personnel
Team Leader	SAE	1
Foreman	Class III	1
Unskilled Worker	Class IV	2
Driver	Class IV	1

**3.4 Tools and Equipment**

The Minor Repair Team shall take following tools and equipment to sites.

**Table 3-3 Tools and Equipment**

Name of tools/equipment	Main Purpose	Number		
		Team Leader	Foreman	Worker
1.Handshovel	Removing debris	1	1	2
2.Shovel	ditto		1	2
3.Broom	ditto			2
4.Brush	ditto	1	1	2
5.Steel brush	Removing rust		1	2
6.Hook with long shaft	Removing obstructions		1	2
7.Hammer	Minor repair	1	1	2
8.Torque wrench	Tensioning Bolt-nut		1	2
9.Paint brush	Painting Steel		1	2
10.Water bucket	Transporting water			2
11.Cloth/Duster	Swiping work		1	2
12.Rope	Safety work		1	2
13.Caulking gun	Injection of caulking mate.		1	
14.Power grinder	Surface treatment		1	
15.Hand chisel	Scrape hard objects off		1	
16.Expand ladder	Approaching to work place		1	
17.Generator	Power supplying		1	
18.Jet water cleaner	Removing debris		1	
19.Vehicle	Team and tool transport		1	

13.



14.



15.



Remark; other Item photos see Table 2-2

### 3.5 Material

The Minor Repair Team shall take following material to sites.

**Table 3-4 Material**

Name of material	Main purpose	Quantity	Remarks
Non-shrinkage cement	Patching repair of concrete	1 pack	
Anti-corrosion paint	Touch up paint, minor repaint	1 can	
Aluminum paint	Touch up paint, minor repaint	1 can	for galvanized member
Epoxy sealant	Caulking, Sealing repair	1 pack	
Epoxy primer	ditto	1 pack	
Bolt-nut and washer set	Adding bolts set	each 10	Prepare several diameters

## **4 Selection of Major Repair Method**

### **4.1 Choose Repair design options**

In principle, all bridges which are listed for Major Repair works should be taken “Detailed Investigation” before the Repair design. The Evaluator should select sorts of “Detailed Investigation” depend on defect. Through the “Detailed Investigation”, the cause and the extension of defect of whole structure are clarified. Then first, the Repair design can start.

Periodic Maintenance Program (PMP) Major maintenance works are generally outsourced to private construction companies. In case of outsourcing the tendering process is as follows.

- a. Detailed Investigation for Repair design is carried out. The results of Detailed Investigation are inputted into BMS database.
- b. Repair design is carried out and tender documents are prepared.
- c. A tender is opened and contract documents are signed.
- d. Repair works are executed and progress of works is monitored.
- e. The results of Repair works are inputted into BMS database.

Major Repair works will be implemented for defects which will affect stability, strength, life length of bridges or bridge elements and safety of traffic. Some of the defects require urgent repair works due to high possibility of collapse.

Major Repair works will be applied to main elements which support the bridge/culvert. For the efficient Major Repair design, following considerations are necessary;

- a. Consider the intended use of the structure
- b. Design life of the structure
- c. Target performance of systems

The Strengthening of existing bridges (Figure 1-1 Type c) is seldom used for deteriorated concrete and steel bridges. Generally, the Strengthening of existing bridges is only considered, if design load is increased and the structural safety is not satisfied for coming traffic load.

The Rehabilitation of deteriorated bridges/culverts is a heavy burden from the socio-economic viewpoint since it leads to significant user costs or budget of nation. As a consequence, novel concepts for the rehabilitation of concrete and steel structures must

be developed and implemented.

However, “25% of the structure owners are unhappy with the performance of the repair and protection materials within 5 years after the rehabilitation; and 75% are dissatisfied within 10 years” (CONREPNET, GB 2004).

#### 4.2 Selection of Repair method for Concrete

After the Inspection and Evaluation of concrete element, the BMS system can select automatically the Repair method of concrete element. However, the final selection of the Repair method or Re-construction should be taken after “Detailed Investigation”. The first phase Selection Flow of Repair method of concrete element for Superstructure and Substructure are shown in Figure 4-1 and Figure 4-2.

The basic Repair methods for concrete element are Crack repair and Restoration. As the injection material is used commonly flexible epoxy resin with crack bridging ability against temperature- and deflection-movement. As the restoration material is used mostly polymer cement mortar with good bonding and flexural strength and less dry shrinkage. For substructure, Fluid recasting concrete and normal concrete are also used.

Selection Flow of Repair Method of Concrete Elements (Superstructure)

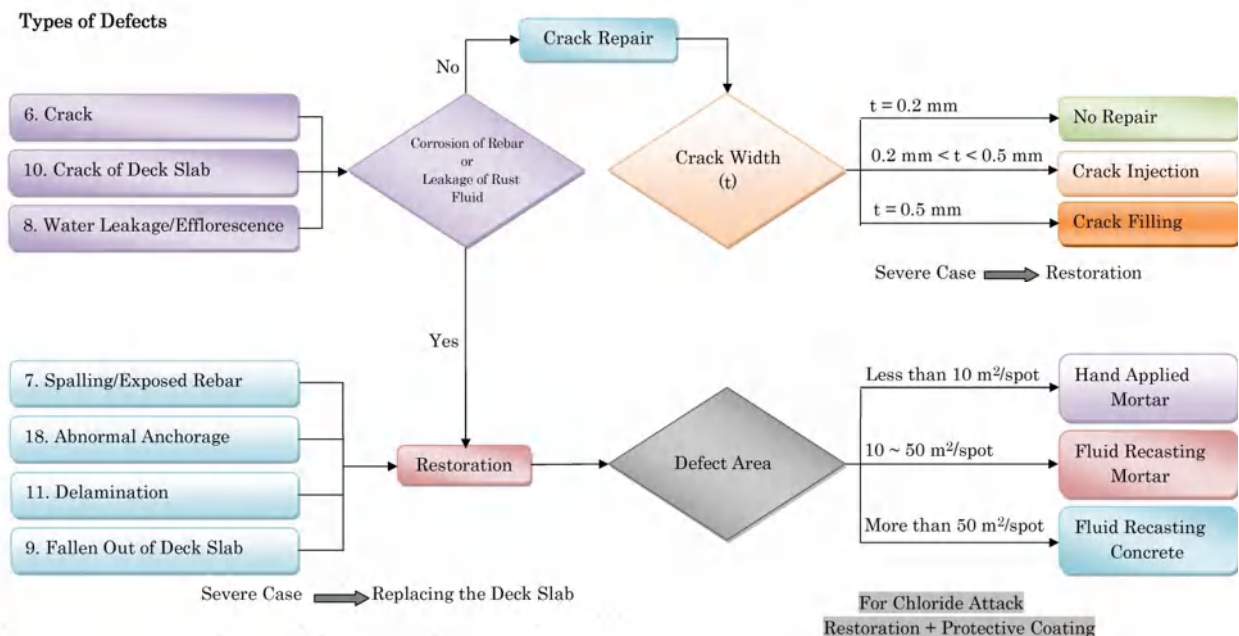
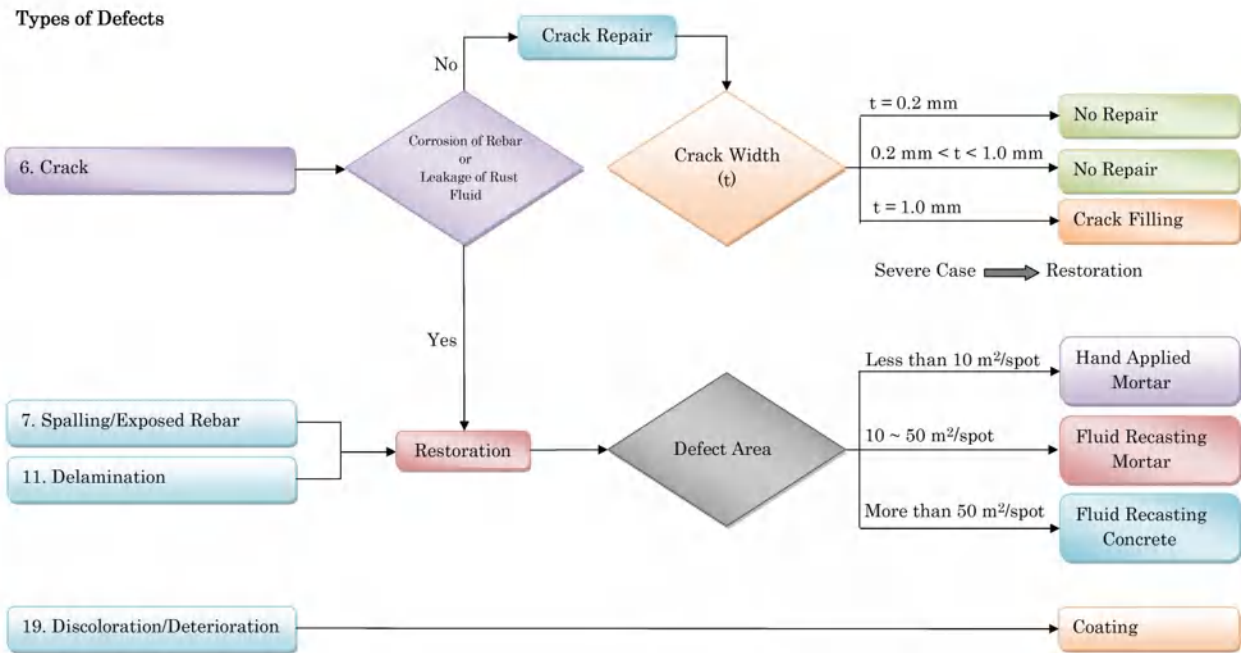


Figure 4-1 Selection Flow of Repair method of Concrete elements (Superstructure)

The Flow based by Local Government Jp

**Selection Flow of Repair Method of Concrete Elements (Substructure)**



**Figure 4-2 Selection Flow of Repair method of Concrete elements (Substructure)**

The Flow based by Local Government Jp

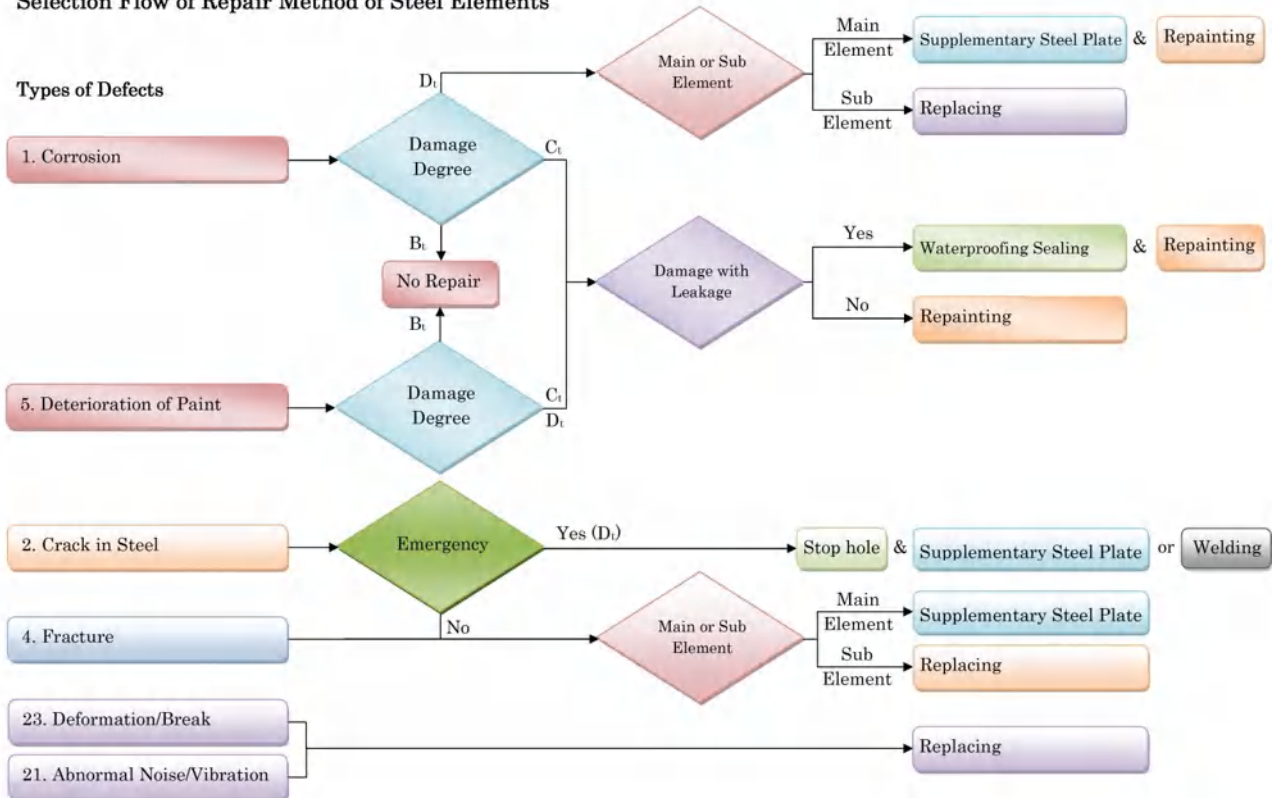
**4.3 Selection of Repair method for Steel**

After the Inspection and Evaluation of steel element, the BMS system can select automatically the Repair method of steel element. However, the final selection of the Repair method or Re-construction should be taken after “Detailed Investigation”. The first phase Selection Flow of Repair method of steel element is shown in Figure 4-3 For Steel Bridges, Main elements such as Main girder, Cross girder, Truss and Pile are repaired by adding steel plates e.g. while Sub elements are replaced to new one.

Welding should be avoided if at all possible in repairing older steel elements since the steel typically has high carbon content.

For Repainting should be considered the partial zone Repainting in regards to the burden of the cost. Mostly corrosion damaged zone is the bridge end.

**Selection Flow of Repair Method of Steel Elements**

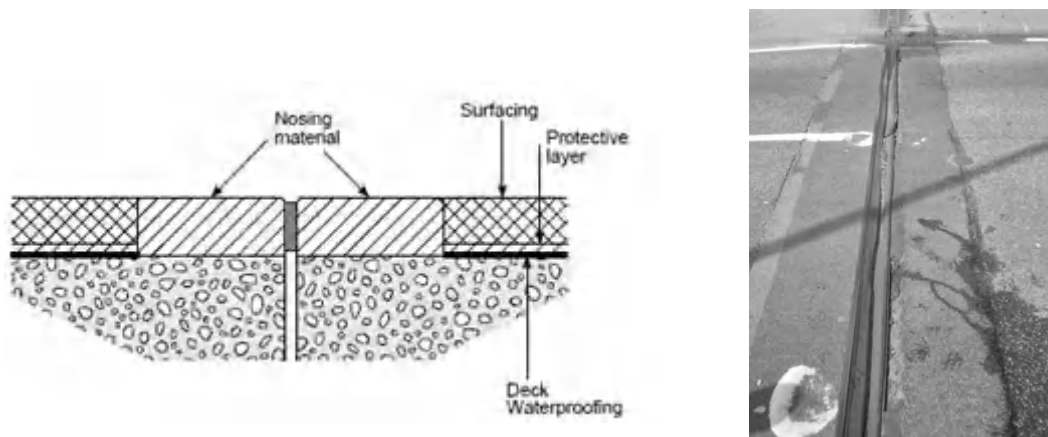


**Figure 4-3 Selection Flow of Repair method of steel elements**

The Flow based by Local Government Jp

**4.4 Selection of Repair method for Expansion joint**

The quality and maintenance of the expansion joints are vital to the behavior of the bridges and its durability. Accordingly, it should be ensured that expansion joints are waterproofed as well as resistant to leakage. In the case of wet carriageway at the joint, leakage water reaches to the bearing seat (Figure 4-4).



**Figure 4-4 Nosing joint with poured seal (left) and its surface damage (right)**

The usual gap of concrete edge is around 20 mm considering temperature here in Bangladesh as  $41^{\circ}\text{C}\sim 7^{\circ}\text{C}$  ( $=24^{\circ}\text{C}\pm 17^{\circ}\text{C}$ ). The thermal movement of the concrete bridge span is;

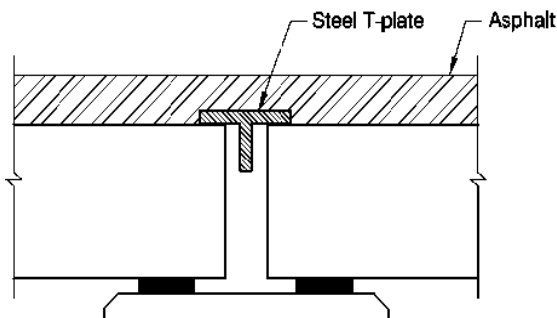
$$\begin{aligned} \Delta \text{ temp} &= \alpha \cdot L \cdot \delta T \\ &= 12 \times 10^{-6} /^{\circ}\text{C} \times 20 \text{ m} \times (\pm 17^{\circ}\text{C}) = \pm 4.1 \text{ mm} \quad \text{for L; } 20 \text{ m} \quad ; \text{ Concrete girder} \\ &= 12 \times 10^{-6} /^{\circ}\text{C} \times 30 \text{ m} \times (\pm 17^{\circ}\text{C}) = \pm 6.1 \text{ mm} \quad \text{for L; } 30 \text{ m} \\ &= 12 \times 10^{-6} /^{\circ}\text{C} \times 40 \text{ m} \times (\pm 17^{\circ}\text{C}) = \pm 8.2 \text{ mm} \quad \text{for L; } 40 \text{ m} \end{aligned}$$

And for steel bridges, the thermal movement is;  $51^{\circ}\text{C}\sim 7^{\circ}\text{C}$  ( $=29^{\circ}\text{C}\pm 22^{\circ}\text{C}$ )

$$\begin{aligned} \Delta \text{ temp} &= \alpha \cdot L \cdot \delta T \\ &= 12 \times 10^{-6} /^{\circ}\text{C} \times 20 \text{ m} \times (\pm 22^{\circ}\text{C}) = \pm 5.3 \text{ mm} \quad \text{for L; } 20 \text{ m} \quad ; \text{ Steel girder} \\ &= 12 \times 10^{-6} /^{\circ}\text{C} \times 30 \text{ m} \times (\pm 22^{\circ}\text{C}) = \pm 7.9 \text{ mm} \quad \text{for L; } 30 \text{ m} \end{aligned}$$

The shrinkage effects can be neglected for the existing bridges, so that the joint movements for above mentioned span length are less than 10 mm. The expansion joint of above mentioned type and span length can be replaced to the type of Buried joint (Figure 4-5). The Asphaltic Plug joint with flexible material over joint is not recommended, because none of the flexible material keeps durability for summer heat of the sunshine in Bangladesh (Figure 4-6).

The merit of Buried joint is continuous pavement and covered the gap with T-formed steel plate and Deck waterproofing. The steel T-plate should be painted and have the width of min. 50 mm.



**Figure 4-5 Buried joint with steel T-plate**



**Figure 4-6 Asphaltic plug joint (left) and its surface damage (right)**

For greater span (40 – 60 m) bridges, Replacement to the suitable water-proof type of Steel Expansion joint is recommended (Figure 4-8).



**Figure 4-7 damaged Expansion Joint**

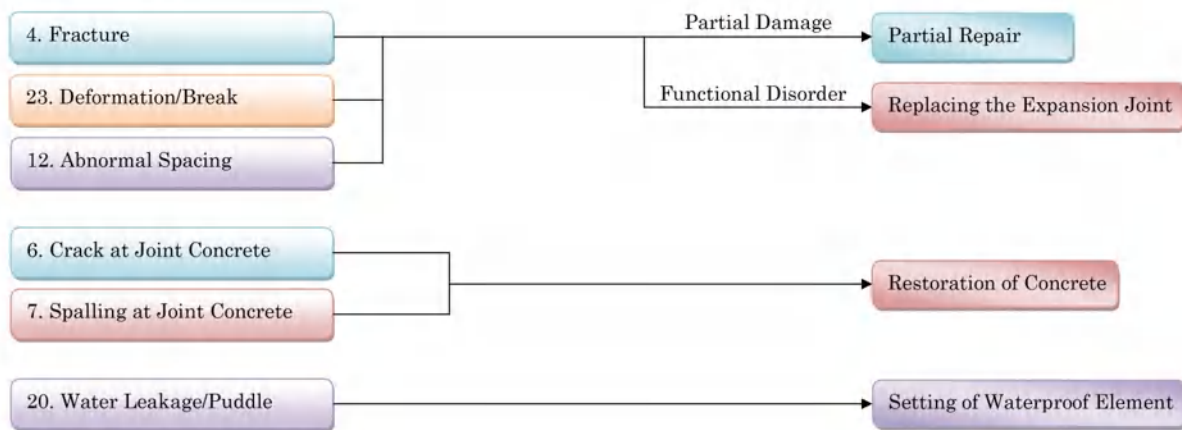


**Figure 4-8 Steel Expansion Joint**

Figure 4-9 shows the general selection flow of Repair method of Expansion joint. If existing Expansion joint is not waterproof, that means water leaking around and under the joint is visible, Replacing to the Buried joint is recommended, if the calculated thermal movement is less than 10 mm. After the Replacement, the joint-less Pavement is comfortable for traffic user.

**Selection Flow of Repair Method of Expansion Joint**

**Types of Defects**



**Figure 4-9 Selection Flow of Repair method of Expansion joint**

The Flow based by Local Government Jp

**“Consideration on the thermal movement of Bridges”**

AASHTO (WSDOT 2015)

Temperature Range 38°C~ -20°C (=9°C±29°C) for concrete  
 49°C~ -20°C (=14.5°C±35°C) for steel

Japan (JRA 2013)

Temperature Range 35°C~ -5°C (=15°C±20°C) for concrete  
 40°C~ -10°C (=15°C±25°C) for steel

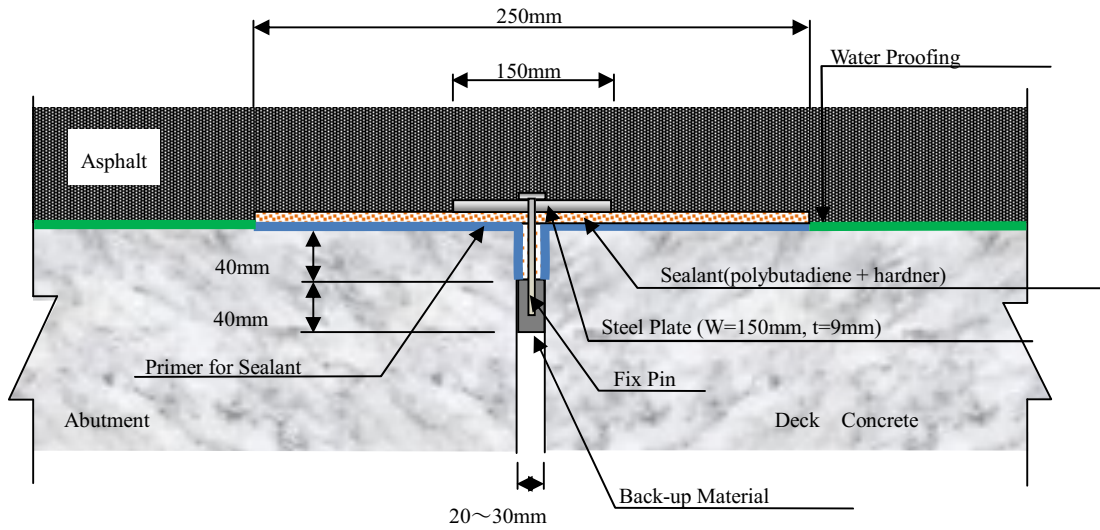
Bangladesh (Bridge Maintenance Manual 2014)

Temperature Range 35°C~7°C (=21°C±14°C) for concrete  
 none for steel

BD Bridge Maintenance Manual 2017 (assumed)

Temperature Range 41°C~7°C (=24°C±17°C) for concrete  
 51°C~7°C (=29°C±22°C) for steel

The higher max. temperatur is based on the measurement at Jamuna Bridge



**Figure 4-10 modified Buried joint with steel T-plate**

#### 4.5 Selection of Repair method for Bearing

Bearings transmit the dead load and the live load on the superstructure to the substructure while also allowing the superstructure to move without exceeding its design stress limits. A bearing assembly that is frozen (corroded or fouled, not moving as intended), out of position, damaged, or for any other reason not operating properly can cause the stress limits to be exceeded in a bridge seat, in beam ends, in supporting columns, or in other bridge members, which in turn will result in structural damage requiring repair or replacement. The cause of most bearing problems are open or leaking Expansion joints, substructure movement, or bridge approach pressure on the superstructure.

The two general types of bridge bearings are “fixed” bearing devices and “expansion” bearing. As a new type of bearing, “elastic” bearing is also developed.

Figure 4-11 shows the general selection flow of Repair method of Bearing. If the “expansion” Bearing is not moving, corrosion or deformation is presumed as the cause.

#### Selection Flow of Repair Method of Bearing

##### Types of Defects



**Figure 4-11 Selection Flow of Repair method of Bearing**

The Flow based by Local Government Jp

#### 4.6 Selection of Repair method for Footing

Bridge Scour is defined as the removal of soil from around foundations. Flowing water transports soils from around a bridge foundation and moves it down stream, leaving the foundations exposed and in some cases undermined. Depending on the severity of the scour a bridge's integrity could be at risk and in some cases lead to a partial or total collapse.

Bridge scour is dynamic and conditions can change rapidly. There are many variables that affect the rate at which bridge scour happens. Two of the primary variables are soil type and water velocity. Some soils are more susceptible to scour than others. Loose unconsolidated soil is easily carried away while hard bedrock layers are generally not susceptible to scour. Also, high flow velocities scour away soils faster than lower velocities.

If this type of damage is not repaired, it could cause catastrophic failure to the bridge. The typical repair for this type of damage is to place large rocks around the pier (Figure 4-12 ). Projects such as this are difficult to permit because they involve placing equipment and materials in environmentally sensitive areas.

Figure 4-13 shows the general selection flow of Repair method of Footing including bridge scour.



Placing Special Heavy Loose Rip Rap

Figure 4-12 Scour repair work by special heavy equipment

#### Selection Flow of Repair Method of Footing

##### Types of Defects

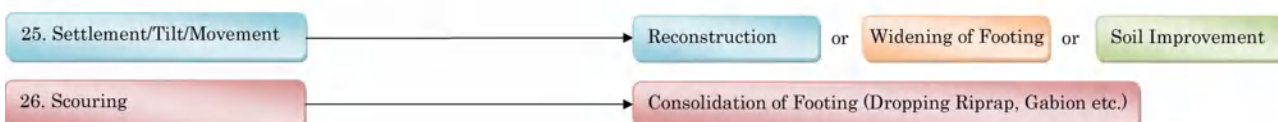


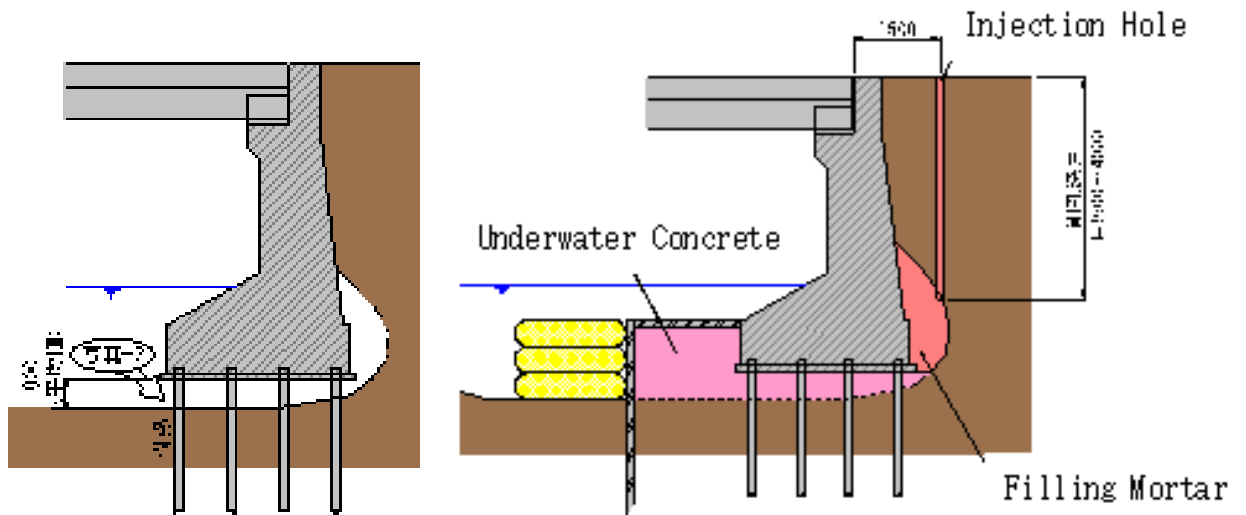
Figure 4-13 Selection Flow of Repair method of Footing

The Flow based by Local Government Jp



**Figure 4-14 Scoured bridge pier (left) and after Repair work (right)**

If the use of the heavy Riprap transport like Figure 4-14 is difficult, then Underwater concrete can be used instead of Riprap. In this case, the repair area is limited by Sheet pile wall (Figure 4-15).



**Figure 4-15 Scour repair work with Underwater concrete and mortar**

#### 4.7 Selection of Repair method for Railing

Railings include any barrier or parapet that runs parallel with the traffic on either side of the bridge. Avoid leaving the end of the bridge rail or a parapet wall exposed to traffic flow. If a bridge rail or barrier has been identified as substandard, at the first rehabilitation opportunity practicable consideration should be taken for upgrading it to the current applicable standard as part of the rehabilitation activity. Repair of collision damage to a section of railing may make complete replacement of the entire run of railing more cost-effective than repair, any substandard railing should be considered for an upgrade replacement in such a situation. Remedy for steel corrosion is basically re-painting.

Figure 4-16 shows a need to Spot painting.



**Figure 4-16 Rusted Railings with Flaking Paint that Require Spot Painting**

#### 4.8 Selection of Repair method for Drainage system

Proper maintenance of deck drainage systems to ensure the flow of water off the deck and away from the structure is just as important as keeping deck joints sealed. It does little good to keep deck joints watertight if the water and any associated contaminants cannot flow away from the bridge structure. Furthermore, if water ponds on the deck, it can result in reduced traction for vehicles crossing the bridge under certain conditions. If the deck drainage is not efficient and effective, dirt and debris may accumulate on the deck and in the joints, leading to increased maintenance requirement for other bridge elements.

Slab drain is desired at the bridge end corner (from curb and expansion joint about 100 mm) to avoid water pond on the deck slab. If waterproofing of the deck slab is

not provided, should be added to the part of the Rehabilitation work of bridges  
(Figure 4-17).



**Figure 4-17 Waterproofing of deck slab (Asphalt compound type)**

## 5. Repair Methods for different Defects

### 5.1 Plate list for Major Repair Methods

Different types of Defect and Remedial measures are shown in the following Table 5-1. Plate 3-1 to Plate 3-20 are attached in the Appendix 2 describing detailed method and procedure for each repair method.

Table 5-1 Major Repair Methods

No	Type of defect	Element	Remedial Measure	Plate No
1	Crack on concrete	Concrete structures	Crack Injection	Plate 3-1
2			Crack Filling	Plate 3-2
3	Spalling/Exposed rebar Abnormal Anchorage	Concrete structures	Hand applied mortar (A) & (B)	Plate 3-3
4	Delamination		Spray applied mortar	Plate 3-4
5	Water leakage/ Efflorescence		Fluid Recasting mortar/concrete	Plate 3-5
6	Discoloration/ Deterioration	Concrete structures	Protective Coating	Plate 3-6
7	Fallen out of deck slab	Concrete deck slab	Partial Replacement of Deck slab	Plate 3-7
8	Crack on concrete Water leakage/ Efflorescence	Concrete deck slab	Carbon Fiber Sheet Bonding	Plate 3-8
9	Crack on concrete	Concrete girder	Carbon Fiber Sheet Bonding	Plate 3-9
10			Carbon Fiber Plate Bonding	Plate 3-10
11	Crack in Steel	Steel girder	Supplementing Steel plate	Plate 3-11
12		Steel Pier	Supplementing Steel plate	Plate 3-12
13	Spalling/Exposed rebar	Bored Pile	Filling Pile mortar/concrete	Plate 3-13
14	Scouring Abnormal spacing	Footing of Substructures	Footing consolidation	Plate 3-14
15	Water leakage/Puddle	Expansion Joint	Replacement of small move joint	Plate 3-15
16	Abnormal spacing		Replacement of steel joint	Plate 3-16
17	Water leakage/ Efflorescence	Concrete deck slab	Waterproofing-Asphalt compound type	Plate 3-17
18	Functional disorder bearing	Bearing	Repainting of steel bearing	Plate 3-18
19	Difference in level		Replacement of rubber bearing	Plate 3-19
20	Defect of reinforcing material	Concrete deck slab	Rebonding of strengthening plate	Plate 3-20




## Appendix 1. Routine Maintenance and Minor Repair Methods Plates

Routine Maintenance Methods and Minor Repair Methods are compiled as Plate style. Compiled Plates are as shown in the following Table 3-1 of the Manual.

Table 3-1 Plate list

Plate name	Defect/Deficiency	Remedial Measure	Page
<b>Routine Maintenance Methods</b>			
Plate 1-1	Debris accumulation	Cleaning	
Plate 1-2	Water flow obstruction	Removing obstructions	
<b>Minor Repair Methods</b>			
Plate 2-1	Material loss from Stone and Mortar masonry	Repairing of stone masonry	
Plate 2-2	Damage of gabion wire mesh	Partial repair of gabion mesh	
Plate 2-3	Spalling, Minor honey comb	Patching	
Plate 2-4	Minor corrosion of steel works	Touchup painting	
Plate 2-5	Abnormal bituminous pavement	Partial repair of pavement	

<b>ROUTINE MAINTENANCE METHODS</b>		
<b>Defect/Deficiency</b>	<b>Debris accumulation</b>	<b>PLATE 1-1</b>
<b>Remedial Measure</b>	<b>Cleaning</b>	
<b>1. Work description</b>		
<p>During the Bridge service life, several components of bridges get unclean due to deposition of foreign materials. Materials that collect on the deck surface flow with the rain water towards the drainage spouts which may choke the outlets and affect drainage. Also the materials that collect on the deck and carried by the rain water towards the expansion joints can pass through any opening present therein and accumulate on the pier cap, abutment caps and around the bearings. Such debris accumulation can cause malfunction of bearings/corrosion in metal bearing since debris tend to hold water. Also growth of vegetation such as grass, shrubs and other plants on the components of bridges is very common.</p> <p>Various 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 shall be thoroughly cleaned of accumulated dust, debris and other foreign materials at regular intervals. This is to prevent deterioration of the bridge, which will therefore preserve the bridge components in their intended conditions resulting in increased service life of the bridge as well as provide safety and comfort to the road users. Areas which have been cleaned shall be ensure freedom from accumulated sand, gravel, dirt, and other foreign materials. Vegetation grown on the components of bridges shall be removed. Also vegetation near the bridge that might affect the normal performance of the bridge, such as free flow of water under the bridge, etc. shall be removed.</p>		
<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p><b>Photo 1-1-1 Cleaning of Bearing by jet water</b></p>  </div> <div style="text-align: center;"> <p><b>Photo 1-1-2 Cleaning using Inspection Vehicle</b></p>  </div> </div>		
<b>2. Application criteria</b>		
<p>Criteria for cleaning applied to the bridge including its steel surface, deck and substructure are recommended below:</p>		

ROUTINE MAINTENANCE METHODS		
Defect/Deficiency	Debris accumulation	PLATE 1-1
Remedial Measure	Cleaning	
<p>1) Surface of steel plate</p> <p>The surface areas of a steel bridge should be cleaned and washed by brushing with fresh water or using high pressure water blasting, including the top and bottom flanges, web plates, diaphragms, lateral members and gusset plates. For convenience, inspection vehicle may be utilized to carry out cleaning of the bridge soffit.</p> <p>Washing of steel bridges should be carried out in the flowing Zones expeditiously;</p> <p>Barisal, Chittagong, Comilla, Dhaka (Southern area), Gopalganj and Khulna. However if salt particles are identified on surfaces of steel bridges after cyclones in other Zones, similar actions are to be taken.</p> <p>2) Bridge deck slab:</p> <p>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.</p> <p>3) Bridge substructure:</p> <p>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.</p> <p>4) Vegetation growth</p> <p>These 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.</p> <p>A few typical examples of debris accumulation have been illustrated following;</p> <p style="text-align: center;"><b>Photo 1-1-3 Vegetation in deck / girder</b></p> 		

**ROUTINE MAINTENANCE METHODS**

<b>Defect/Deficiency</b>	<b>Debris accumulation</b>	<b>PLATE 1-1</b>
<b>Remedial Measure</b>	<b>Cleaning</b>	

**Photo 1-1-4 Joint clogged with sand and dust      Photo 1-1-5 Ponding on deck**



**Photo 1-1-6 Debris on bearing**

**Photo 1-1-7 Vegetation on substructure**

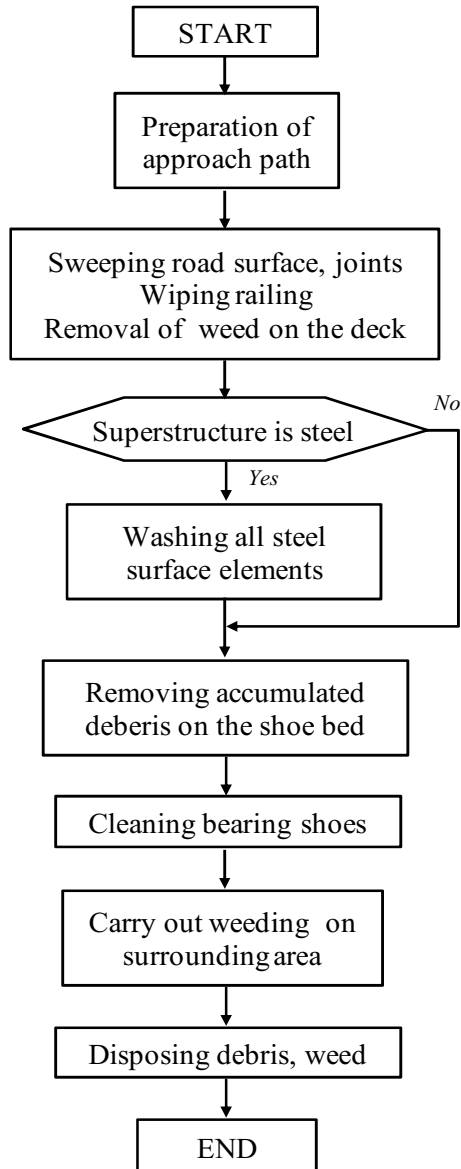


**3. Work sequence**

Work sequence of Removing of obstructions is as shown Figure 1-1-1.

ROUTINE MAINTENANCE METHODS		
Defect/Deficiency	Debris accumulation	PLATE 1-1
Remedial Measure	Cleaning	

**Figure 1-1-1 Work sequence**



#### 4. Required Equipment/Tool and Material

##### 4.1 Required Materials


- Clean water suitable for cleaning

##### 4.2 Required Tools/Equipment

- Refer Table 2-2 Tools and Equipment

<b>ROUTINE MAINTENANCE METHODS</b>		
<b>Defect/Deficiency</b>	<b>Debris accumulation</b>	<b>PLATE 1-1</b>
<b>Remedial Measure</b>	<b>Cleaning</b>	
<b>5. Requirement, Specification</b>		
<p>5.1 Material Requirement</p> <p>Water to be used for cleaning of the bridge components 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.</p> <p>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.</p> <p>5.2 Work Requirement</p> <p>1) General</p> <p>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. At no time shall these materials be allowed to be disposed into the river or on dry land portions below the bridge.</p> <p>2) High pressure water</p> <p>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.</p> <p>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.</p> <p>The Contractor shall flush out the interior surfaces of all girders and truss members</p>		

<b>ROUTINE MAINTENANCE METHODS</b>		
<b>Defect/Deficiency</b>	<b>Debris accumulation</b>	<b>PLATE 1-1</b>
<b>Remedial Measure</b>	<b>Cleaning</b>	
<p>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.</p> <p>The Contractor shall obtain approval of the source of water used. They shall use fresh water which is free of sediments and salt contaminants and be responsible for all expenses involved in securing the approved water.</p>		
<b>6. Measurement and Payment</b>		
<p>6.1 Method of Measurement:</p> <p style="padding-left: 40px;">Bridge cleaning shall be taken as a lump sum item.</p> <p>6.2 Basis of Payment:</p> <p style="padding-left: 40px;">For bridge cleaning, the Contractor shall be paid a lump sum contract price. 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.</p>		
<u>Pay Item No.</u>	<u>Name</u>	<u>Unit of Measurement</u>
1-1	Cleaning	Lump sum (L/P)

<b>ROUTINE MAINTENANCE METHODS</b>		
<b>Defect/Deficiency</b>	<b>Water flow obstruction</b>	<b>PLATE 1-2</b>
<b>Remedial Measure</b>	<b>Removing obstructions</b>	
<b>1. Work description</b>		
<p>Many times floating debris and drifting shrubs, weeds, vegetation, wood, etc. are transported by flowing water in the stream which pile up around the bridge substructure, causing obstruction to flow under the bridge. This is caused by factors such as course of the river, shape of pier, and where the span length is less or the opening height is less. Piers having rounded edges and solid webs reduce debris accumulation. Heavily forested areas will generate more floating debris than non-forested areas.</p> <p>The obstruction caused in the stream channel by the accumulated debris will tend to trap and accumulate additional debris. These accumulations divert and constrict the flow of water, which increases the velocity of flow and creates turbulence in the flow, both of which have the potential of erosion of bed and bank.</p> <p>The works dealt herein involve removal of such drifting shrubs, weeds, vegetation, wood, etc. around piers and adjacent to abutments and disposal to a designated area.</p>		
<b>2. Application criteria</b>		
<p>If the driftwoods and debris around the piers and sides of the abutments are not cleared from time to time as and when they are lodged and allowed to accumulate instead, it becomes more and more difficult to dislodge them in course of time, which may result in flow irregularity under the bridge causing an increase in velocity flow leading to scouring, etc. Removal and disposal of driftwoods and debris shall be carried out once a year, or after occurrence of floods when necessary.</p>		
<b>Photo 1-2-1 Driftwoods and debris around the piers</b>		
		

**ROUTINE MAINTENANCE METHODS**

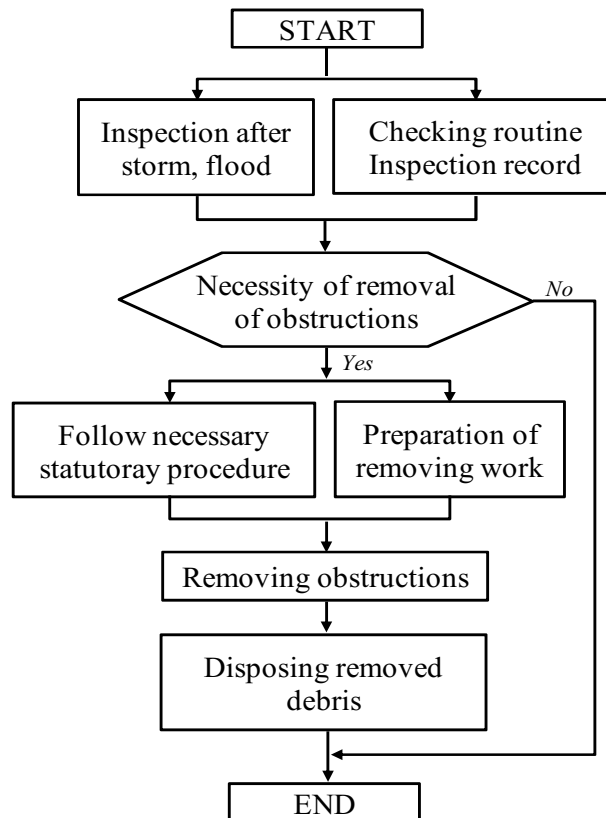
<b>Defect/Deficiency</b>	<b>Water flow obstruction</b>	<b>PLATE 1-2</b>
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<b>Remedial Measure</b>	<b>Removing obstructions</b>
-------------------------	------------------------------

**3. Work sequence**

Work sequence of Removing of obstructions is as shown in Figure 1-2-1.

**Figure 1-2-1 Work sequence of Removal of obstructions**



**4. Required Equipment/Tool and Material**

4.1 Required Materials


- None

4.2 Required Equipment/Tools

- Electric saw
- Dump truck
- Back Hoe
- Inspection vehicle (For scaffolding), if necessary

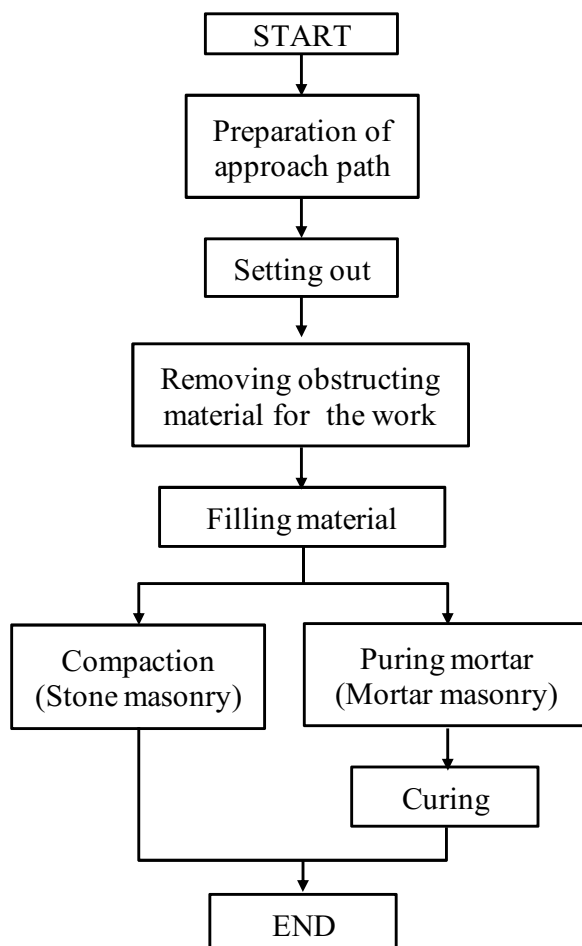
<b>ROUTINE MAINTENANCE METHODS</b>		
<b>Defect/Deficiency</b>	<b>Water flow obstruction</b>	<b>PLATE 1-2</b>
<b>Remedial Measure</b>	<b>Removing obstructions</b>	
<b>5. Requirement, Specification</b>		
<p>5.1 Work requirement</p> <p>1) Inspection and Checking of the Routine inspection record</p> <p>After heavy storms, bridge sites should be routinely checked to determine the need for removing debris. All structures shall be checked at least once a year. If maintenance record indicates that debris accumulation is a common problem, bridges shall be checked more frequently.</p> <p>2) Preparation</p> <p>Assess the requirement and make arrangement for accessing the driftwood and debris piles up around the bridge components. In some cases it may be necessary to install scaffolding for the purpose of removal. Inspection vehicle with scaffolding device may be useful for this purpose.</p> <p>3) Statutory procedure</p> <p>The contractor shall take all necessary statutory permissions for the works before commencement of activities. Permission from private property owners shall be taken lawfully when it is necessary to remove debris from private property. Locations requiring extensive work should be specially referred to hydraulic engineering staff as well as conservation and environmental analyst.</p> <p>4) Removing obstructions</p> <p>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.</p> <p>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.</p>		
<b>6. Measurement and Payment</b>		
<p>6.1 Method of Measurement</p> <p>This works will be measured by cubic meter or by lump sum for sites described on the plans.</p> <p>6.2 Basis of Payment</p>		

<b>ROUTINE MAINTENANCE METHODS</b>		
<b>Defect/Deficiency</b>	<b>Water flow obstruction</b>	<b>PLATE 1-2</b>
<b>Remedial Measure</b>	<b>Removing obstructions</b>	
<p>This work will be paid based on a unit price per cubic meter for "Removal and Disposal of Driftwood and Plants", complete in place, which include full compensation for cutting, loading, hauling, disposing of driftwoods and cleaning the right of way at each location noted on the plans and for all labor, equipment, tools, and other necessary accessories to complete the work.</p>		
<b>Pay Item No.</b>	<b>Name</b>	<b>Unit of Measurement</b>
1-2	Removing obstructions	lump sum (L/P)

<b>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Material loss from Stone and Mortar masonry</b>	<b>PLATE 2-1</b>
<b>Remedial Measure</b>	<b>Repairing of stone masonry</b>	
<b>1. Work description</b>		
<p>Under severe storm conditions of and floods particularly during monsoon, hydraulic force during heavy flow in the waterway sometimes causes loss of bricks/stone from masonry, gabion mattress, and protection works</p> <p>The work in this section involves restoration of the missing stones / bricks from the masonry work, gabion mattress and protection works, caused by the scouring effect of flooding.</p>		
<b>2. Application criteria</b>		
<p>It is important that restoration of the missing stones / bricks from the masonry work, gabion mattress and protection works is carried out early to avoid consequential damages such as slope failures. If left unattended to at the early stages, it becomes more and more difficult to repair the damage making the bridge components vulnerable to damages. Stone pitching shall be carried out where necessary.</p> <p style="text-align: center;"><b>Photo2-1: Missing stone in existing masonry work</b></p> <div style="text-align: center;">  </div>		
<b>3. Work sequence</b>		
<p>Work sequence of Removing of obstructions is as shown Figure 2-1-1.</p>		

MINOR REPAIR METHODS		
Defect/Deficiency	Material loss from Stone and Mortar masonry	PLATE 2-1
Remedial Measure	Repairing of stone masonry	

**Figure 2-1-1 Work sequence of Removal of obstructions**



#### 4. Required Equipment/Tool and Material

##### 4.1 Required Materials

- Sound stone/brick/concrete blocks
- Cement-sand mortar
- Water for curing

##### 4.2 Required Equipment/Tools

- Hand tools for removing existing damaged stone / brick / concrete block masonry and for laying new masonry

<b>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Material loss from Stone and Mortar masonry</b>	<b>PLATE 2-1</b>
<b>Remedial Measure</b>	<b>Repairing of stone masonry</b>	

## 5. Requirement, Specification

### 5.1 Material

Material to be used for this work shall be obtained with prior approval by the engineer in charge.

### 5.2 Work requirement

#### 1) Necessity of early repair work

Repairing the damaged masonry / gabion / protection works affected by loss of bricks, stones, concrete blocks, etc. as applicable is essential during the early stage of routine maintenance to avoid more elaborate and difficult repair in future. Delay in taking up the repair of the damages in protection work may eventually lead to failure of the slope or other protected works. Stone/brick/concrete block patching shall be carried out when necessary.

#### 2) 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.

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.


#### 3) Mortar masonry

Bricks / stones in mortared masonry work shall be laid in full bed of mortar, with joints completely filled with mortar and shove into place as applicable. Due to any reason if it becomes necessary to move or shift unit which have been already laid remove the setting mortar, then clean, and apply fresh new mortar for final placement. Coursing and mortar joints must be done in accordance with the direction of the Engineer. Bricks / stones shall be laid and anchors must be installed as shown in the drawing and directed.

#### 4) Supplemental masonry

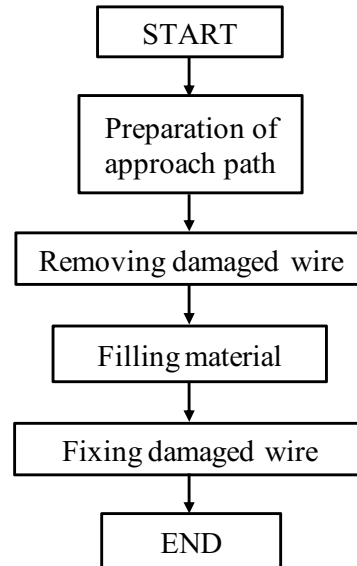
Where new stone masonry is placed into the existing masonry wall, joints shall be partially or completely set. Exposed surface of the existing stone masonry shall be cleaned with wire brush and lightly moisten so as to attain best possible bonding with the new work.

<b>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Material loss from Stone and Mortar masonry</b>	<b>PLATE 2-1</b>
<b>Remedial Measure</b>	<b>Repairing of stone masonry</b>	
<p>5) Curing</p> <p>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.</p>		
<b>6. Measurement and Payment</b>		
<p>6.1 Method of Measurement</p> <p>These works will be measured by cubic meter or by lump sum for sites described on the plans.</p>		
<p>6.2 Basis of Payment</p> <p>This work will be paid based on a unit price per cubic meter for "Restoration of stone to Stone masonry " and "Restoration of stone to Mortar masonry", or on lump sum basis, complete in place, which 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.</p>		
Pay Item No.	Name	Unit of Measurement
2-1-(1)	Repairing Stone masonry (1)	Cubic meter (m <sup>3</sup> )
2-1-(2)	Repairing Stone masonry (2)	Lump sum (L/P)
2-1-(3)	Repairing Mortar masonry (1)	Cubic meter (m <sup>3</sup> )
2-1-(4)	Repairing Mortar masonry (2)	Lump sum (L/P)

<b>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Damage of gabion wire mesh</b>	<b>PLATE 2-2</b>
<b>Remedial Measure</b>	<b>Partial repair of gabion mesh</b>	
<b>1. Work description</b>		
<p>Gabion mattresses are used for protection of river banks, bed as well as for protection of abutments and piers. At monsoon, under severe conditions of storms / floods, hydraulic force during heavy flow in the river sometimes cause damage to the gabion steel wire mesh due to abrasion, particularly if they are corroded.</p> <p>The work herein comprises restoration of the gabion works by replacing the damaged wires.</p>		
<b>2. Application criteria</b>		
<p>Replacing the damaged wires of gabions at the early stage as a part of routine maintenance is essential. Otherwise the damage is likely to increase and may eventually give way to the stone /brick infill out of the gabion basket, increasing the risk of failure of the protection work and making it more and more difficult and costly to repair the damage.</p> <p style="text-align: center;"><b>Photo-2-2: Deterioration in gabion wire mesh</b></p> <div style="text-align: center;">  </div>		
<b>3. Work sequence</b>		
<p>Work sequence of Removing of obstructions is as shown Figure 2-2-1.</p>		

MINOR REPAIR METHODS		
Defect/Deficiency	Damage of gabion wire mesh	PLATE 2-2
Remedial Measure	Partial repair of gabion mesh	

**Figure 2-2-1 Work sequence of Removal of obstructions**



#### 4. Required Equipment/Tool and Material

##### (1) Required Materials

- Wire mesh
- Wires for tying
- Infill materials such as stones, bricks, concrete blocks to match the existing

##### (2) Required Equipment/Tools

- Wire cutter
- Pliers and hand tools for binding of steel wires
- Cleaning equipment comprising hand tools, shovel, and any other tool

#### 5. Requirement, Specification

##### 5.1 Work requirement

###### 1) Inspection


Inspect and identify all deteriorated and damaged parts of the existing gabion protection work.

###### 2) Preparation of work

Proper access arrangement for the work shall be ensured.

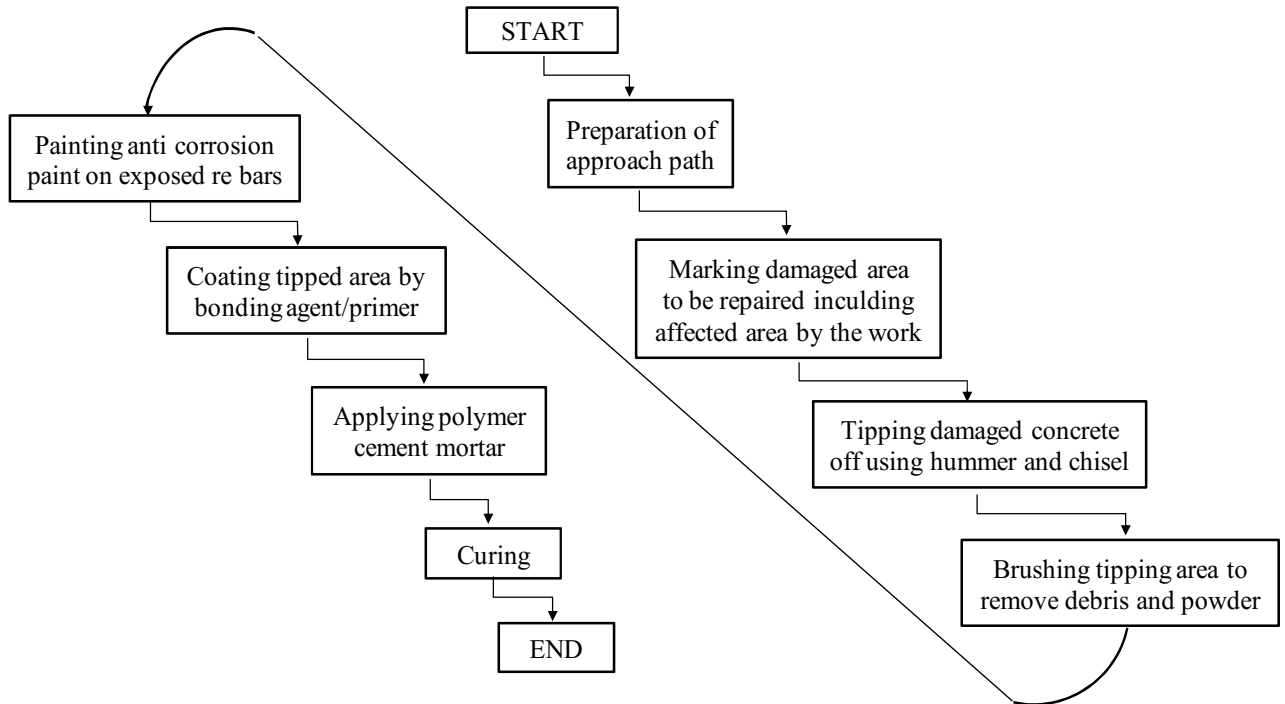
Removing damaged mesh wire

<b>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Damage of gabion wire mesh</b>	<b>PLATE 2-2</b>
<b>Remedial Measure</b>	<b>Partial repair of gabion mesh</b>	
<p>Carefully cut and remove the damaged/unacceptable portions of the gabion wires.</p> <p>While removing the damaged wires, care shall be exercised not to disturb the existing portion of the gabion work which is in intact condition.</p> <p>3) Filling missing material</p> <p>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.</p> <p>4) Fixing wire mesh</p> <p>Place new gabion wire mesh over the damaged existing 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.</p> <p>Upon completion of works, remove all material, tools and equipment from the site.</p>		
<b>6. Measurement and Payment</b>		
<p>(1) Method of Measurement</p> <p>This works will be measured by square meter or by lump sum for sites described on the plans.</p> <p>(2) Basis of Payment</p> <p>This work will be paid based on a unit price per square meter for "Partial replacement of gabion wire mesh", or on lump sum basis, complete in place, which 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.</p>		
Pay Item No.	Name	Unit of Measurement
2-2-(1)	Partial repair of gabion mesh	Lump sum (L/P)
2-2-(2)	Partial repair of gabion mesh	Square meter (m <sup>2</sup> )

<b>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Spalling, Minor honey comb</b>	<b>PLATE 2-3</b>
<b>Remedial Measure</b>	<b>Patching</b>	
<b>1. Work description</b>		
<p>Spalling of concrete requiring patching is usually caused by corrosion of steel reinforcement. Honeycomb is the effect of inadequate compaction of concrete while being cast.</p> <p>Patching is a temporary repair measure unless all the chloride-contaminated concrete is removed before the deck is patched. If only the spalled and delaminated concrete is removed, the corrosion process continues and additional spalling can soon appear.</p> <p>Studies of deck-sealing practice suggest that while sealing or overlaying of chloride contaminated concrete cannot stop the process of corrosion and deterioration of steel and concrete, it can slow the process, which may be acceptable depending upon the schedule of future major rehabilitation.</p> <p>Potholes in deck sometimes require a temporary patch, while in some other cases a “permanent patch” may be the best. They should not be left unattended if these are severe enough to affect the riding quality of the deck. Further, wheels of moving vehicles hitting potholes increases the impact loading, which can result in increased damage.</p> <p style="text-align: center;">Photo 2-3-1 Spalling Concrete</p> <div style="text-align: center;">  </div>		
<b>2. Application criteria</b>		
<p>Spalling of width less than 300 mm and depth less than 50mm have been dealt with here. The repair comprises application of polymer cement repair mortar on the spalled 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.</p>		
<b>3. Work sequence</b>		
<p>Work sequence of Epoxy Coating is as shown Figure 2-3-1.</p>		

MINOR REPAIR METHODS		
Defect/Deficiency	Spalling, Minor honey comb	PLATE 2-3
Remedial Measure	Patching	

Figure 2-3-1 Work sequence



#### 4. Required Equipment/Tool and Material

##### 4.1 Material List

- Polymer Cement Mortar
- Portland Cement
- Epoxy Bonding
- Zinc rich primer

##### 4.2 Tool/Equipment List

- Chisel
- Portable Generator
- Wire Brush

#### 5. Requirement, Specification

##### 5.1 Material Specifications

The material shall be approved by the Engineer through mill certificate of the supplier.

- 1) Polymer Cement

## MINOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Spalling, Minor honey comb</b>	<b>PLATE 2-3</b>
<b>Remedial Measure</b>	<b>Patching</b>	

Polymer cement mortar shall conform to the requirements of the specifications shown in Table 2-3-1 or equivalent ASTM Specifications.

Table 2-3-1 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	$2.0 \times 10^{-5}$ mm/mm/°C
Slant shear bond to concrete	ASTM C882	Concrete failure above 15 N/mm <sup>2</sup>
Compressive strength	ASTM D695M	above 20 N/mm <sup>2</sup>

### 2) Epoxy bonding agent

The epoxy bonding agent to concrete surface shall conform to the requirements of the specification indicated in Table 2-3-2. (Anti-corrosion zinc rich primer shall be applied to exposed rebar).

Table 2-3-2 Specification of Epoxy Bonding Agent to Concrete Surface

Property	Test Method	Specification
Compressive strength	ASTM D695M	70 N/mm <sup>2</sup>
Flexural strength	ASTM D790M	40 N/mm <sup>2</sup>
Tensile strength	ASTM D638M	30 N/mm <sup>2</sup>
Tensile shear bond to steel	ASTM 1002	15 N/mm <sup>2</sup>
Slant shear bond to mortar	ASTM C882	15 N/mm <sup>2</sup>
Bond Strength of Cured Concrete to Fresh Concrete	ASTM D7274	15 N/mm <sup>2</sup>

### 3) Zinc Rich Primer

The zinc rich primer to rebar shall be in accordance with the requirements of the specifications in Table 2-3-3.



Table 2-3-3 Specification of Zinc Rich Primer for Rebar



Property	Test Method	Unit	Specifications
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 Film Test	-	%	$87.5 \pm 2$

## 5.2 Work requirement

### 1) General

Patching repair works using Portland cement mortar shall be carried out in accordance with

<b>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Spalling, Minor honey comb</b>	<b>PLATE 2-3</b>
<b>Remedial Measure</b>	<b>Patching</b>	
<p>provisions of relevant standards and manufacturer’s specifications. Patching, as a minor repair 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:</p>		
<p>2) Marking of patching area</p> <p>Evaluate surface area to be patched using hammer for hollow sounding delaminated area (or by using instruments to detect unsound concrete).</p> <p>Mark the area to be patch-repaired with paint or marker. Ensure complete coverage of the damage.</p>		
<p>3) Tipping damaged concrete off</p> <p>Using a small sledge hammer and chisel, remove all damaged concrete at the edges and corners of area to be repaired. Use a wire brush to remove loose debris. Care should be taken to ensure that no reinforcement is damaged.</p> <div style="display: flex; align-items: center;"> <div style="flex: 1;"> <p>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 designated Engineer.</p> <p>Patch areas that are within 600 mm of each other should be combined into a single large patch.</p> <p>If necessary, provide formwork around the damaged concrete to straighten the edges of the damaged section.</p> </div> <div style="flex: 0.5; text-align: center;">  </div> </div>		
<p>4) Coating tipping area</p> <p>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.</p> <p>Care shall be taken to ensure that vibration associated with the repair works does not cause delamination of existing adjacent plaster or concrete.</p>		
<p>5) Applying bonding agent and anti corrosion paint</p> <p>Apply bonding agent to the damaged area in order for the patch material to adhere. Additionally concrete nails/bids may be set to reinforce the repair.</p> <div style="display: flex; align-items: center;"> <div style="flex: 1;"> <p>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 designated Engineer.</p> </div> <div style="flex: 0.5; text-align: center;">  </div> </div>		

<b>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Spalling, Minor honey comb</b>	<b>PLATE 2-3</b>
<b>Remedial Measure</b>	<b>Patching</b>	
<p>If rebar is exposed, anticorrosion coating should be applied on the bar surface prior to patching.</p>		
<p>6) Patching mortal</p>		
<p>Prepare the mortar mix in a bucket using equipment approved by the Engineer. Use a trowel to spread fresh mortar over the area, covering the concrete nails driven halfway in the old concrete. Smoothen and level the mortar with a trowel. Polymer cement mortar is suitable for both vertical and horizontal surface applications, with a thin coating of up to 15 mm.</p>		
<p>7) Finishing</p>		
<p>As may be required, the mortar surface can be smoothed using a trowel or broom finished. 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.</p>		
<p>The Engineer may approve repair mortar application thickness of up to 50 mm for lightweight mortars, provided the mortar manufacturer furnishes technical data to justify a layer thickness of greater than 20 mm.</p>		
<p>8) Curing</p>		
<p>All types of concrete repair with repair mortar need thorough and continuous curing to develop strength and impermeability. Curing also minimizes drying shrinkage while bond strength is developing. Curing of the repair mortar shall be in accordance with the manufacturer's instructions related to the polymer modified additive. Where curing agents are specified by the manufacturer, they shall be applied immediately after the surfaces have been scarified for the next repair mortar layer, or troweled to a finish.</p>		
<b>6. Measurement and Payment</b>		
<p><b>6.1 Measurement</b></p> <p>Area prepared for patching shall be measured in square meter after removal of concrete of</p>		

**MINOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Spalling, Minor honey comb</b>	<b>PLATE 2-3</b>
<b>Remedial Measure</b>	<b>Patching</b>	

required thickness over the marked area of delaminated concrete identified by the Engineer.

**6.2 Payment**

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

<u>Pay Item No.</u>	<u>Name</u>	<u>Unit of Measurement</u>
2-3	Patching	Square Meter (m <sup>2</sup> )

**MINOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Minor corrosion of steel element</b>	<b>PLATE 2-4</b>
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<b>Remedial Measure</b>	<b>Touchup painting</b>
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**1. Work description**

Due to thin paint coverage on steel surfaces or formation of pin-holes in paint, the steel surface may get exposed to atmosphere resulting in initiation of corrosion. Touch up painting at the early stages prevents progress of corrosion.

Work included in this section comprises field touchup painting on steel members at localized areas including surface preparation and other associated works. This section covers only painting on relatively small affected areas which can be carried out with the use of small power tools / hand tools. Painting of larger areas requiring sand blast cleaning should be carried out in accordance with the specifications covered under major repairs.

**2. Application criteria**

Touchup painting shall be done locally on partially rusted steel surfaces. Depending on the area affected by corrosion, two different surface preparations have been suggested :

**Table 2-4-1 Degree of rusting and surface preparation**

Affected area	Description of degree of rusting	Surface preparation	Reference Photos of surface preparation	
			Before	After
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	Photo4-1	Photo4-3
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	Photo4-2	Photo4-4

**Steel surfaces affected by corrosion**

Photo4-1 Surface area of 10~20% rusting



Photo4-2 Surface area of 20~30 rusting



MINOR REPAIR METHODS		
Defect/Deficiency	Minor corrosion of steel element	PLATE 2-4
Remedial Measure	Touchup painting	

### Corrosion affected steel surfaces after surface preparation

Photo4-3 Less severe corrosion



Photo4-4 More severe corrosion



If the paint condition is identified as Grade-1 (affected surface 10-20%), aluminum paint shall be applied with a similar shade.

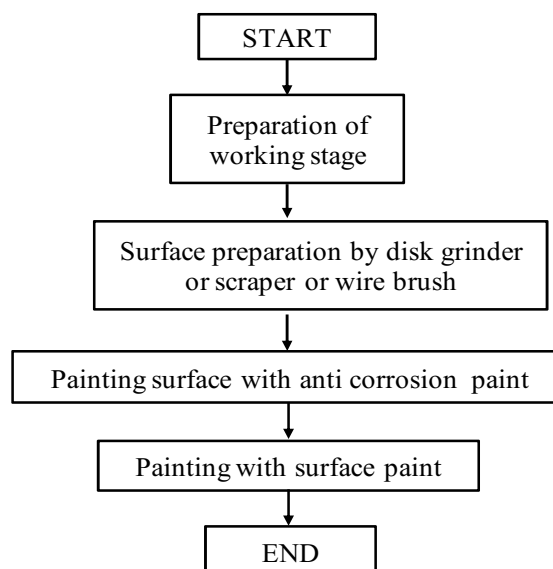
Where condition of paint is evaluated as Grade-2 (affected surface 20-30%) with loss of section within 20%, special anticorrosion paint shall be applied to restrict corrosion from progressing further.

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.

### 3. Work sequence

Work sequence of Epoxy Coating is as shown in Figure 2-4-1.

**Figure 2-4-1 Work sequence**



## MINOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Minor corrosion of steel element</b>	<b>PLATE 2-4</b>
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<b>Remedial Measure</b>	<b>Touchup painting</b>
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### 4. Required Equipment/Tool and Material

#### 4.1 Materials

- Aluminum paint / special anticorrosion paint as required
- Thinner
- Epoxy resin filler

#### 4.2 Tools/Equipment/

- Scaffolding, inspection vehicle
- Portable generator (3 kVA)
- High pressure water blaster (8.0Mpa, 10.0 liters/min.)
- Sandpaper, portable power disk grinder
- Paint brush, roller

### 5. Requirement, Specification

#### 5-1 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 2-4-2 Specification of Aluminum paint**

Tests	Test Reference	Specifications
Adhesive test	ASTM D7234	7days 1.0 N/mm <sup>2</sup> , 28days 1.5 N/mm <sup>2</sup>
Elongation	ASTM C190	7days 0.40 %, 28days 0.40 %
Saltwater test	ASTM D6943	No defection

#### 5-2 Work requirement

##### 1) 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>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Minor corrosion of steel element</b>	<b>PLATE 2-4</b>
<b>Remedial Measure</b>	<b>Touchup painting</b>	
<p>2) Preparation of Steel Surface:</p> <p>Surface preparation shall conform to the paint manufacturer's specifications. Hand or power tools shall be applied for cleaning the surface</p> <p>Groves 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.</p> <p>Application of aluminum paint material shall be in accordance with the manufacturer's specifications and as approved by the Engineer.</p> <p>3) Application of Touchup Paint</p> <p>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.</p> <p>Total dry film thickness for special anticorrosive paint shall be 500<math>\mu</math>m (equivalent 1.5kg/m<sup>2</sup>) consisting of two layers of coating as follows:</p> <ul style="list-style-type: none"> <li>- Layer-1: 250<math>\mu</math>m</li> <li>- Layer-2: 250<math>\mu</math>m</li> </ul> <p>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 <math>\mu</math>m.</p> <p>Royal paint is recommended for galvanized member touchup painting.</p> <p>Total dry film thickness for Royal paint shall be 80<math>\mu</math>m (equivalent 0.5kg/m<sup>2</sup>) consisting of two layers of coating as follows:</p> <ul style="list-style-type: none"> <li>- Layer-1: 40<math>\mu</math>m</li> <li>- Layer-2: 40<math>\mu</math>m</li> </ul> <p>Royal paint shall be applied in accordance with the stipulations of paint manufacturer's specifications.</p>		

MINOR REPAIR METHODS		
Defect/Deficiency	Minor corrosion of steel element	PLATE 2-4
Remedial Measure	Touchup painting	

## 6. Measurement and Payment

### 6.1 Method of Measurement

The work shall be measured as the accepted surface area treated and painted, in square meters.

### 6.2 Basis of Payment

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 Item No.	Name	Unit of Measurement
2-4	Touchup painting	Square Meter (m <sup>2</sup> )

MINOR REPAIR METHODS		
Defect/Deficiency	Abnormal bituminous pavement	PLATE 2-5
Remedial Measure	Partial repair of pavement	

**1. Work description**

A **pothole** is a structural failure in an asphalt pavement, caused by the presence of water in the underlying soil structure and the traffic passing over the affected area. Infiltration of water into the underlying soil structure first weakens the supporting soil. Then the traffic fatigues and breaks the poorly supported asphalt surface in the affected area. Continued traffic action ejects both asphalt and the underlying soil material to create a hole in the pavement.

Photo5-1 Pothole



Pothole patching methods fall into two distinct categories: temporary and semi-permanent. Temporary patching is reserved for weather conditions that are not favorable to a more permanent solution and usually uses a cold mix asphalt patching compound placed in an expedient manner to temporarily restore pavement smoothness. Semi-permanent patching uses more care, at first the deteriorated base material is replaced and then the hot-mix asphalt fill is applied on that new base material.

**2. Application criteria**

The asphalt is typically an emulsion. Care must be taken with the weather on the day of construction – ideally, a warm day with low humidity is preferred. A bituminous surface treatment should never be constructed on rainy days or when rain is predicted. Rain can dilute the asphalt binder if it has not yet cured, bringing the binder to the top of the cover aggregate; after the water evaporates, tires can pick up the loose aggregate or track binder across the surface.

Asphaltic patch materials consist of a binder and aggregate that comes in two broad categories, hot mix and cold mix. Hot mixes are used commonly. They are produced at local asphalt plants or at site. However, types of cold mix are recommended for fast and easy repair of temporary repair of pavement. Some types of cold mix are pre-packed asphalt compound material and can be obtained quickly for the throw-and-roll repair method of potholes. The patching method can also be taken for the repair of “difference in level” at expansion joint or at bridge deck drainage.

## MINOR REPAIR METHODS

Defect/Deficiency

Abnormal bituminous pavement

PLATE 2-5

Remedial Measure

Partial repair of pavement

### 3. Work sequence

Work sequence of Partial repair of pavement is as shown in Figure 2-5-1.

Figure 2-5-1 Work sequence

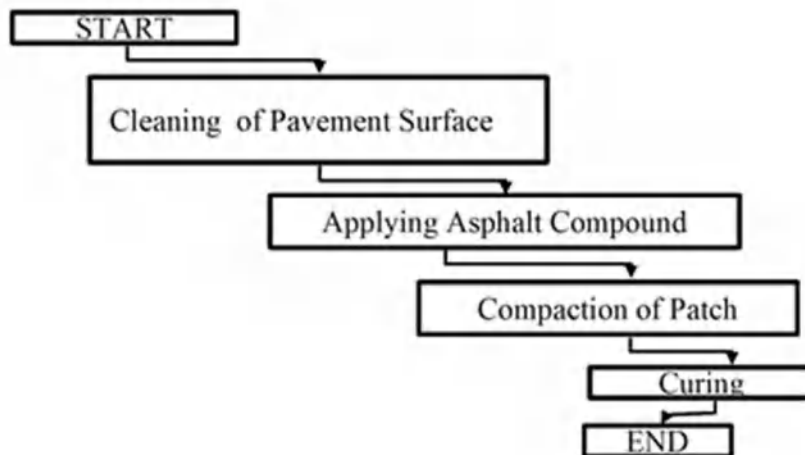


Photo5-2 Surface Cleaning



Photo5-3 Patching of Repair Material



Photo5-4 Completion



**MINOR REPAIR METHODS****Defect/Deficiency****Abnormal bituminous pavement****PLATE 2-5****Remedial Measure****Partial repair of pavement****4. Required Equipment/Tool and Material**

## 4.1 Equipment/Tool

Following equipment/tool is necessary for Patching of Asphalt compound:

- Kettle with Heater
- Shovel
- Broom and Trowel (a small handheld tool with a flat, pointed blade)
- compacting Wheel

## 4.2 Material

- Asphalt Compound

**5. Requirement, Specification**


## 5-1 Material

## 1) Asphalt Compound

Hot-mix asphalt compound patching material shall conform to the requirements of the specifications shown in Table 2-5-1, or equivalent ASTM Specifications. Cold mix compound shall be followed by each producer's regulations.

**Table 2-5-1 Specification of Asphalt Compound**

<b>Property</b>	<b>Test Method</b>	<b>Unit</b>	<b>Specification</b>
Penetration with Conic Needle	ASTM D217	mm	2 ~ 5
Melting Temperature	ASTM D3461	°C	80
Elongation	ASTM D 638	%	3.5
Tensile Strength	ASTM D 638	Kgf/cm <sup>2</sup>	300

<b>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Abnormal bituminous pavement</b>	<b>PLATE 2-5</b>
<b>Remedial Measure</b>	<b>Partial repair of pavement</b>	
<p>5-2 Work requirement</p> <p>1) Preparation of Pavement Surface</p> <p style="padding-left: 40px;">Pavement surfaces adjacent to the pothole shall be cleaned by broom or an air jet, and free from puddle.</p> <p>2) Application of Asphalt compound</p> <p style="padding-left: 40px;">Apply approximately 10 mm higher level of asphalt compound to each pothole, as recommended by each working instruction of manufacturer.</p> <p>3) Curing</p> <p style="padding-left: 40px;">After application, perform until the hot asphalt compound temperature become under 40°C. For cold mix asphalt compound shall be kept by each working instruction of manufacturer.</p>		
		<p>Photo5-5 Applied hot mix</p> 
<b>6. Measurement and Payment</b>		
<p>6-1 Method of Measurement</p> <p style="padding-left: 40px;">This work shall be measured for payment by the actual volume of used patching material where compound is applied, as determined and approved by the engineer.</p> <p>6-2 Basis of Payment</p> <p style="padding-left: 40px;">This work will be paid based on a unit price per liter volume for the pothole or other damages which shall include full compensation for supplying all labor, materials, tools, equipment, and incidental items. This also includes performing all the works involved in preparing the surfaces of existing pavement and application of asphalt compound, as specified on plans and specifications, and as directed by the engineer.</p>		
Pay Item No.	Name	Unit of Measurement
2-5	pavement repair	Liter



## Appendix 2. Major Repair Methods Plates

Major Repair Methods are compiled as Plate style. Compiled Plates are as shown in the following Table 5-1 of the Manual.

Table 5-1 Major Repair Methods

No	Type of defect	Element	Remedial Measure	Plate No
1	Crack on concrete	Concrete structures	Crack Injection	Plate 3-1
2			Crack Filling	Plate 3-2
3	Spalling/Exposed rebar Abnormal Anchorage	Concrete structures	Hand applied mortar (A) & (B)	Plate 3-3
4	Delamination		Spray applied mortar	Plate 3-4
5	Water leakage/ Efflorescence		Fluid Recasting mortar/concrete	Plate 3-5
6	Discoloration/ Deterioration	Concrete structures	Protective Coating	Plate 3-6
7	Fallen out of deck slab	Concrete deck slab	Partial Replacement of Deck slab	Plate 3-7
8	Crack on concrete Water leakage/ Efflorescence	Concrete deck slab	Carbon Fiber Sheet Bonding	Plate 3-8
9	Crack on concrete	Concrete girder	Carbon Fiber Sheet Bonding	Plate 3-9
10			Carbon Fiber Plate Bonding	Plate 3-10
11	Crack in Steel	Steel girder	Supplementing Steel plate	Plate 3-11
12		Steel Pier	Supplementing Steel plate	Plate 3-12
13	Spalling/Exposed rebar	Bored Pile	Filling Pile mortar/concrete	Plate 3-13
14	Scouring Abnormal spacing	Footing of Substrct.	Footing consolidation	Plate 3-14
15	Water leakage/Puddle	Expansion Joint	Replacement of small move joint	Plate 3-15
16	Abnormal spacing		Replacement of steel joint	Plate 3-16
17	Water leakage/ Efflorescence	Concrete deck slab	Waterproofing-Asphalt compound type	Plate 3-17
18	Functional disorder bearing	Bearing	Repainting of steel bearing	Plate 3-18
19	Difference in level		Replacement of rubber bearing	Plate 3-19
20	Defect of reinforcing material	Concrete girder	Rebonding of strength sheet	Plate 3-20

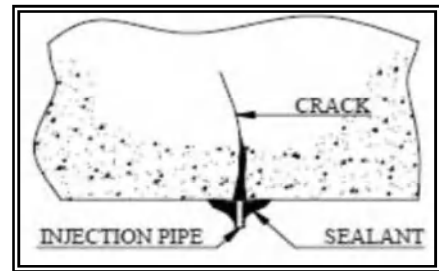
## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete</b>	<b>PLATE 3-1</b>
<b>Remedial Measure</b>	<b>Crack Injection</b>	

### 1. Work description

This method involves crack repairs to concrete structures, particularly to deck slab as shown in Figure 3-1-1. The works include preparation of concrete surface, insertion of pipe fittings bonded with adhesive, injection of epoxy, curing and conducting performance test.

**Figure 3-1-1 Epoxy Injection Method**



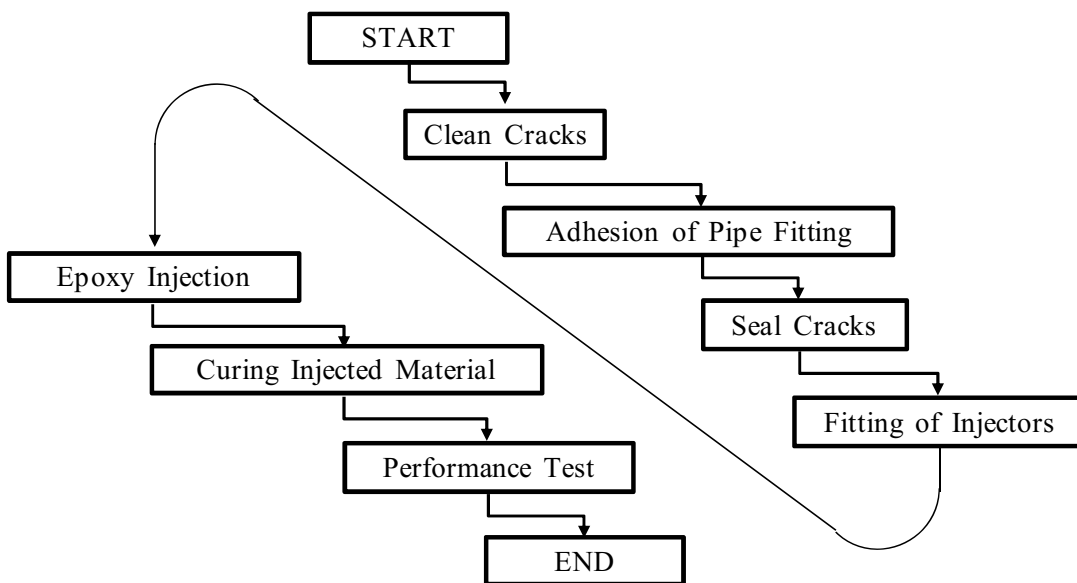
Crack injection for concrete requires highly skilled process and its effectiveness depends mostly on the proficiency of the certified technician. The technician should be qualified based on his experience and approved by the Engineer-in-Charge.

Materials and injection tools developed by the supplier or manufacturer shall be in conformity with JIS, ASTM standards or equivalent.

### 2. Work sequence

Work sequence of Crack Injection Method is as shown in Figure 3-1-2.

**Figure 3-1-2 Work Sequence**



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete</b>	<b>PLATE 3-1</b>
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<b>Remedial Measure</b>	<b>Crack Injection</b>
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### 3. Required Equipment/Tool and Material

1) Equipment/Tools

The following are necessary for Crack Injection:

- Epoxy Injection Pump or Gun
- Power Disc Grinder/Cutter
- Portable Generator -Brush etc.

2) Material

The following materials are used for Crack Injection:

- Epoxy Resin
- Sealant
- Injection port

### 4. Requirement, Specifications

4-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier.

1) Epoxy Resin

The epoxy resin shall be compatible with the concrete of structure and shall have the properties shown in Table 3-1-1. Testing of said properties shall be in accordance with the relevant standards shown in Table 3-1-2, or equivalent ASTM Specifications.

**Table 3-1-1 Specification of Epoxy Resin (for Deck Slab)**

Property	Test Method	Unit	Specification
Viscosity (cPs)	ASTM D2393	mPa.s	500/below
Potlife	-	min	30

**Table 3-1-2 Specification of Epoxy Resin (for Deck Slab)**

Property	Test Method	Unit	Specification
Specific Gravity	ASTM D792	-	$3.30 \pm 0.1$
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	20 /above
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	10/above
Tensile Shear Bond to Steel	ASTM D1002	N/mm <sup>2</sup>	15 /above
Slant Shear Bond Strength to Concrete	ASTM C882	N/mm <sup>2</sup>	15/above
Bond Strength to Concrete Dry / Wet	ASTM D7234	N/mm <sup>2</sup>	1.5

2) Sealant

The epoxy based sealant material shall be compatible with the injection material and shall have the properties listed in Table 3-1-3 below. Testing of materials shall be in

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete</b>	<b>PLATE 3-1</b>
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<b>Remedial Measure</b>	<b>Crack Injection</b>
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accordance with the listed standards or equivalent ASTM Specifications.

**Table 3-1-3 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 <sup>2</sup>	15/above
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	50 /above
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	15 /above
Tensile Shear Bond Strength	ASTM D1002	N/mm <sup>2</sup>	10 /above

### 4-2 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.

#### 1) Clean the cracks.

All loose debris such as dirt, concrete fine particles and contaminants (oil, grease, etc.) are removed from the cracks using high-pressure water, or special solvent. Blow away the residual water or solvent in the crack with filtered (dust and oil free) compressed air and allow adequate time 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 spalled 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.

#### 2) Adhesion of pipe fitting

Connect the terminal of the injector to the pipe

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete</b>	<b>PLATE 3-1</b>
<b>Remedial Measure</b>	<b>Crack Injection</b>	

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 are 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 prepared cracks shall be allowed to cure for at least 12 hours.

### 3) Epoxy Injection

Epoxy shall be injected using air-activated injecting guns as shown in Figure 3-1-3.

Injection is performed on the pipe fitting. Duration of the injection operation shall be in accordance with the supplier's instructions.

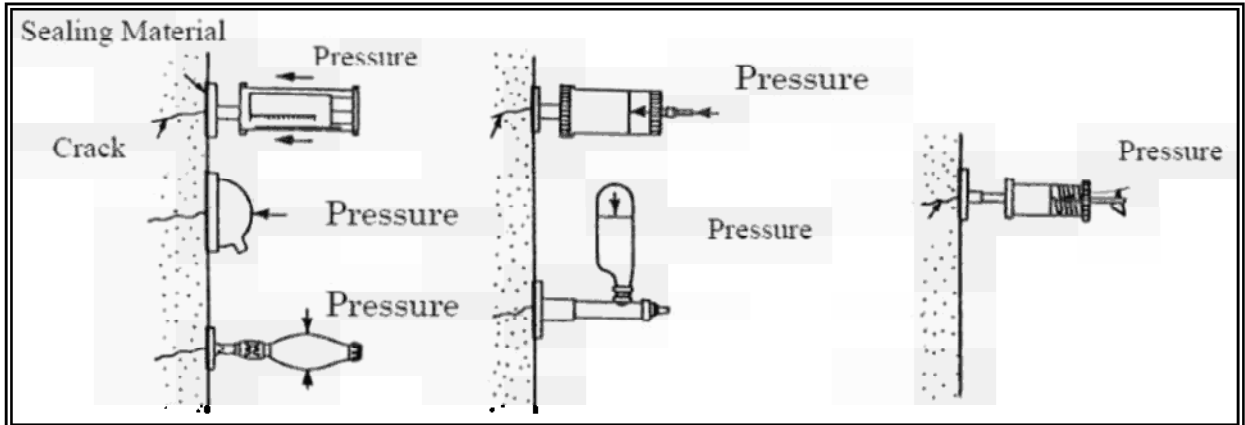
If the crack is vertical, commence the injection of epoxy at the lowest pipe fitting, until the epoxy exudes from the pipe fitting above. For horizontal cracks, the injection is carried out from one end of the crack to the other, in a similar manner. Using a 5 cm width strap, epoxy sealant is applied on the area around the pipe fitting and cracks allowing it to harden.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete</b>	<b>PLATE 3-1</b>
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<b>Remedial Measure</b>	<b>Crack Injection</b>
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**Figure 3-1-3 Crack injection method**



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 works commence, the Contractor should 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°C or is above 35°C. Only intact package of epoxy resin shall be used for each injection purpose. No part packs or on-site batching will 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.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete</b>	<b>PLATE 3-1</b>
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<b>Remedial Measure</b>	<b>Crack Injection</b>
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4) 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.



5) 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.

### 5. Method of Measurement and Payment

5-1 Method of Measurement

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, which are identified by the Engineer.

5-2 Basis of Payment

The contract price paid per meter 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 Item No.	Name	Unit of Measurement
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3-1	Crack Injection	Linear Meter (m)
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**MAJOR REPAIR METHODS**

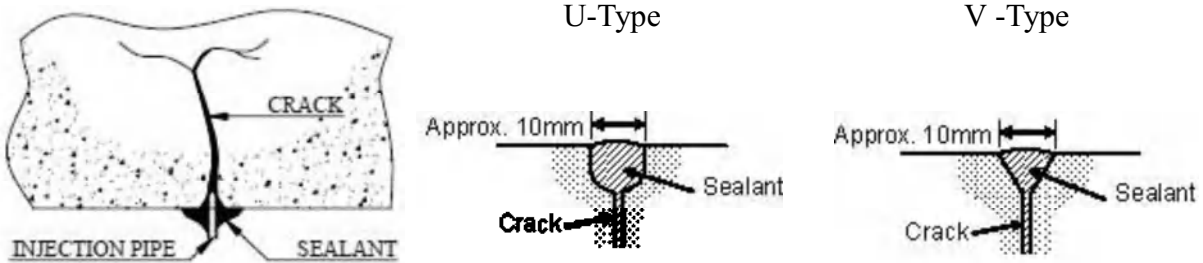
<b>Defect/Deficiency</b>	<b>Crack on Concrete</b>	<b>PLATE 3-2</b>
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<b>Remedial Measure</b>	<b>Crack Filling</b>
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**1. Work description**

Active cracks are treated as movement joints and repaired with flexible sealants as shown in Figure 3-2-1. The sealant is generally installed in a wide recess cut along the crack. The dimensions of the recess (width and depth) depend on the total crack movement and the cyclic movement capability of the joint sealant used. For selection of sealant material, crack movement should be calculated taking into account the applied loads, shrinkage and temperature variations.

**Figure 3-2-1 Type of Filling**



**2. Application criteria**

Crack widths should be more than 0.5 mm with depth of less than 300 mm. In this case, the top surface edges should be chipped or sawn to form ditch of V-type or U-type, in order to provide a filling for inlet of gravity flow of resin into the crack by injection pump.

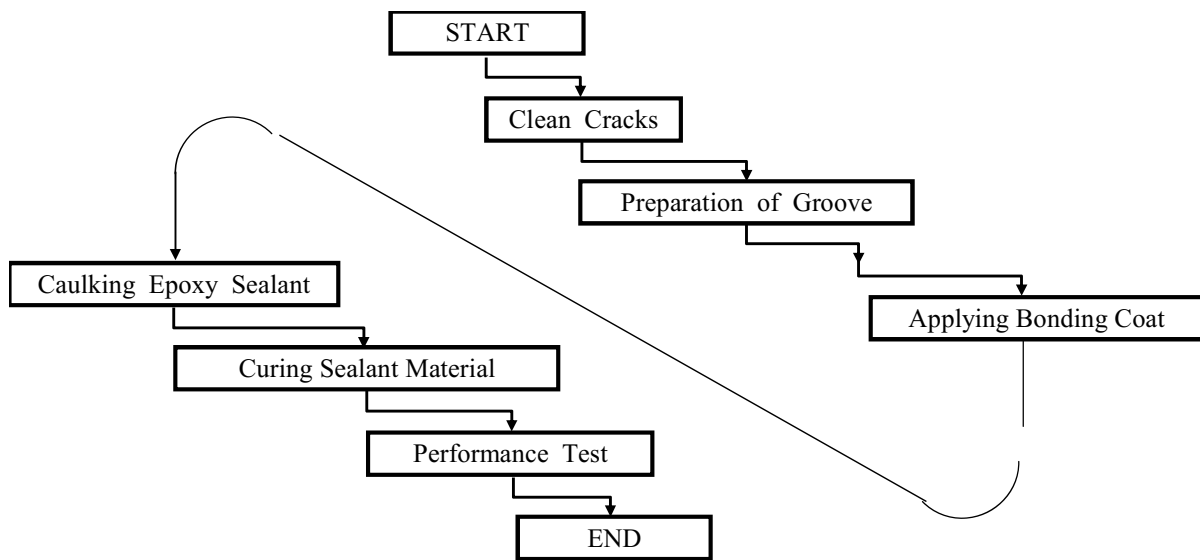
Cracks wider than 0.5 mm generally require epoxy based injection material (mix of epoxy and mineral filler).

**3. Work sequence**

Work sequence of Filling is as shown Figure 3-2-2.

MAJOR REPAIR METHODS		
Defect/Deficiency	Crack on Concrete	PLATE 3-2
Remedial Measure	Crack Filling	

Figure 3-2-2 Work Sequence



#### 4. Required Equipment/Tools and Material

##### 1) Tools/Equipment

The following tools/equipment are necessary for Filling:

- Caulking Gun
- Power Disc Grinder/Cutter
- Portable Generator
- Brush

##### 2) Materials

The following materials are necessary for Filling:

- Epoxy Primer
- Sealant

#### 5. Requirements, Specifications

##### 5-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier.

Testing of materials shall be in accordance with the relevant standards shown or equivalent ASTM Specifications.

##### 1) Epoxy bonding primer

Epoxy bonding primer shall conform to the Specifications as shown in Table 3-2-1 below.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete</b>	<b>PLATE 3-2</b>
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<b>Remedial Measure</b>	<b>Crack Cut Filling</b>
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**Table 3-2-1 Specifications of Epoxy Bonding Primer**

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	70
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	40
Tensile Strength	ASTM D638M	N/mm <sup>2</sup>	30
Tensile Shear Bond to Steel	ASTM D1002	N/mm <sup>2</sup>	10
Slant Shear Bond to Mortar	ASTM C882	N/mm <sup>2</sup>	15

2) Sealant

The epoxy-based sealant material shall be compatible with the injection material and shall have the properties listed in Table 3-2-2.

**Table 3-2-2 Specification of Epoxy Based Sealant**

Property	Test Method	Unit	Specification
Specific Gravity	ASTM D792	-	1.5 ± 0.3
Elongation	ASTM D638	%	50
Bond Strength to Concrete Dry /Wet	ASTM C882	N/mm <sup>2</sup>	3.0

5-2 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.

1) Preparation of concrete

Remove all loose debris such as dirt, concrete fine particles and contaminants (oil, grease, etc) from the cracks using high-pressure water, or special and effective solvent.

Blow away the residual water or solvent in the crack with filtered (dust and oil free)

compressed air and allow adequate time 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

## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Crack on Concrete**

**PLATE 3-2**

**Remedial Measure**

**Crack Filling**

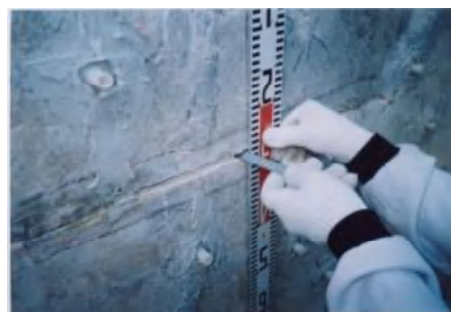
conditions.

Loose or spalled 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.

2) Preparation of Groove

Using a concrete saw, hand tools or pneumatic tools, prepare a minimum 10 mm wide x 10 mm deep V-groove or U-groove, as shown in Fig 3-2-1, at the surface along the crack. Clean the groove with an oil free air jet or wire brush before placing the bonding coat.



3) 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 substrata 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.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete</b>	<b>PLATE 3-2</b>
<b>Remedial Measure</b>	<b>Crack Filling</b>	

4) 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 taking into account 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.



5) 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.

6) 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.



**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Crack on Concrete</b>	<b>PLATE 3-2</b>
<b>Remedial Measure</b>	<b>Crack Filling</b>	

**6. Method of Measurement and Payment**

6-1 Method of Measurement

The method of measurement to determine payment for the Filling works shall be based on the total lengths of the cracks, which are identified by the Engineer-in-Charge.

6-2 Basis of Payment

The contract price paid per meter 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 Item No.	Name	Unit of Measurement
3-2	Crack Filling	Linear Meter (m)

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Spalling, Abnormal Anchorage</b>	<b>PLATE 3-3</b>
<b>Remedial Measure</b>	<b>Hand applied Mortar (A) &amp; (B)</b>	

**1. Work description**

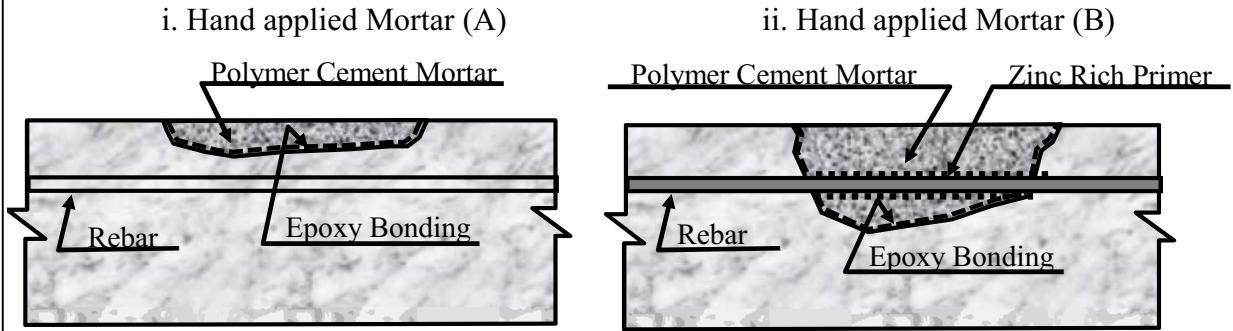
Hand applied Mortar (Patching) repair is performed to restore small areas where sound concrete is damaged by spalling, scaling and/or impact. This method of repair is generally applied using trowel and require minimum or formworks. The patch thickness is limited to a maximum of 100 mm depth of hollow surface.

Hand applied Mortar repair is classified into two types as shown in Figure 3-3-1, considering defective area and surface.

Hand applied Mortar (A) is for defects without exposed rebars while Hand applied Mortar (B) is applied to surfaces with exposed rebars.

Hand applied Mortar repairs may be composed of Polymer cement mortars or non-shrinkage cement mortars depending on the type of patching, location and extent of damage.

**Figure 3-3-1 Hand applied Mortar**



**2. Application Criteria**

Hand applied Mortar (A) is applicable to surfaces without exposed rebars, having defective widths of up to 300mm and depths of up to 50 mm.

Hand applied Mortar (B) is for surfaces with exposed rebars, with defective widths between 300 mm and 600 mm, and up to 100 mm depths.

To keep good bond ability to the existing concrete, Polymer cement mortar is applied in Hand applied Mortar (A) and Mortar (B).

**3. Work sequence**

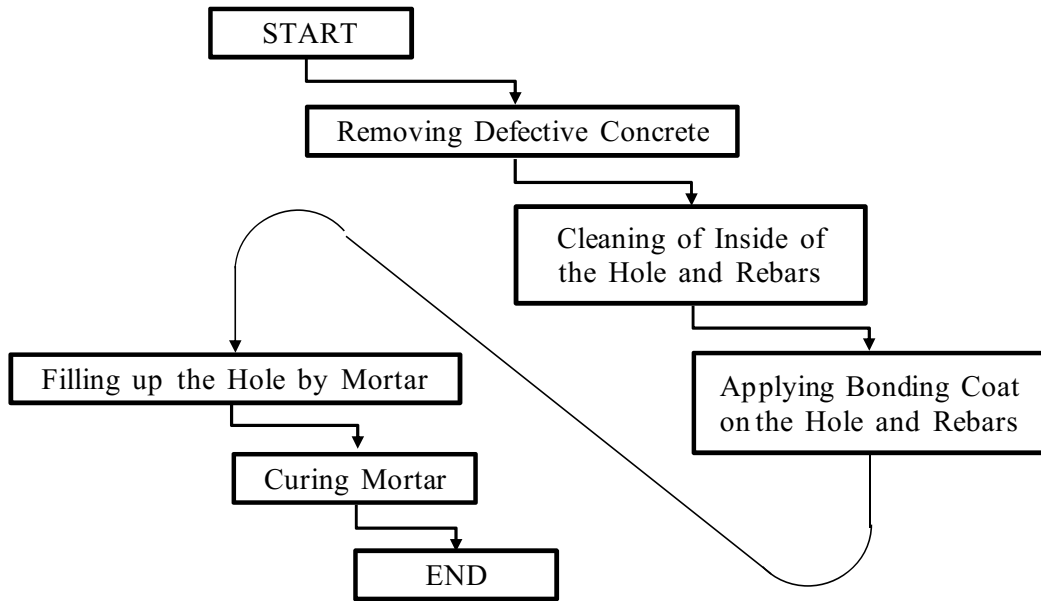
Work sequence of Hand applied Mortar (A) and (B) is shown in Figure 3-3-2.

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Spalling, Abnormal Anchorage</b>	<b>PLATE 3-3</b>
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<b>Remedial Measure</b>	<b>Hand applied Mortar (A) &amp; (B)</b>
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**Figure 3-3-2 Work sequence**



**4. Required tools/equipment and material**

1) Tools/Equipment

For Hand applied Mortar (A) and Hand applied Mortar (B):

- Power Disc Grinder
- Portable Generator
- Brush

2) Material

Hand applied Mortar (A):

- Polymer Cement
- Epoxy Bonding Coat

Hand applied Mortar (B)

- Polymer Cement
- Epoxy Bonding Coat
- Zinc Rich Primer

**5. Requirement, Specifications**

5-1 Material

Material shall be approved by the Engineer through mill certificate of the supplier.

- 1) Polymer Cement

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Spalling, Abnormal Anchorage</b>	<b>PLATE 3-3</b>
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<b>Remedial Measure</b>	<b>Hand applied Mortar (A) &amp; (B)</b>
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Polymer cement mortar shall conform to the requirements of the specifications shown in Table 3-3-1 or equivalent ASTM Specifications.

**Table 3-3-1 Specifications of Polymer Cement**

Property	Test Method	Unit	Specification
Thermal Expansion	ASTM C531	mm/mm°C	2.0 x 10 <sup>-5</sup>
Slant Shear Bond to Concrete	ASTM C882	N/mm <sup>2</sup>	1.5 /above
Compressive Strength (7days x 20°C)	ASTM C579	N/mm <sup>2</sup>	20 /above

2) Corrosion Protective Coating

The Protective Coating of rebar shall conform with the requirements of the specifications in Table 3-3-2.

**Table 3-3-2 Specifications of Corrosion Protective Coating to Rebar**

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	75
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	40
Tensile Strength	ASTM D638M	N/mm <sup>2</sup>	30
Tensile Shear Bond to Steel	ASTM D1002	N/mm <sup>2</sup>	10
Slant Shear Bond to Mortar	ASTM C882	N/mm <sup>2</sup>	15

3) Zinc Rich Primer

The zinc rich primer to rebar shall be in accordance with the requirements of the specifications in Table 3-3-3.

**Table 3-3-3 Specifications of Zinc Rich Primer to Rebar**

Property	Test Method	Unit	Specifications
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 Film Test	-	%	87.5 ± 2

5-2 Work requirement

The Contractor shall submit the Methodology (Procedures) to the Engineer-in-Charge for his review and approval before commencement of the work.

## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Spalling, Abnormal Anchorage**

**PLATE 3-3**

**Remedial Measure**

**Hand applied Mortar (A) & (B)**

1) Removal of defective concrete

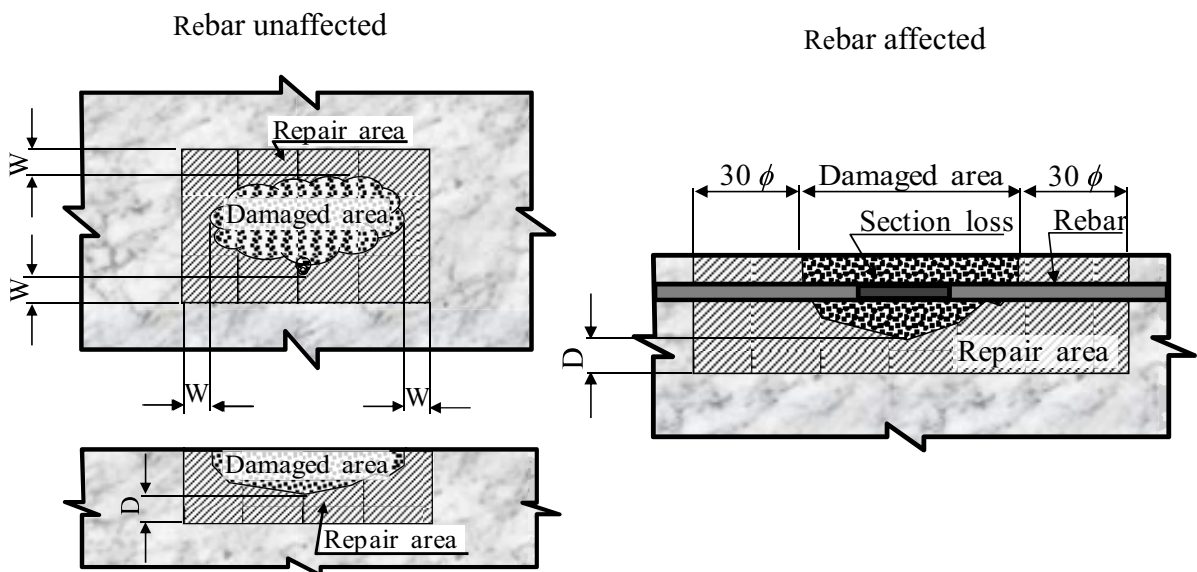
Remove all defective, unsound and contaminated concrete and prepare the edges for the patch area as shown in the attached photo.

If local corrosion in reinforcement with section loss is found, which would require additional bars, remove only the damaged concrete including the length needed to bond the new reinforcement as shown in Figure 3-3-3.

**Removal of defect concrete**



**Figure 3-3-3 Preparation of concrete surface for Hand applied Mortar**



Note: **W** and **D** shall be at least 20mm

Concrete within marked out areas shall be removed using light mechanical breakers or hammer and chisel, the exposed reinforcement shall be cut and the sound of concrete substrate shall be determined to the satisfaction of the Engineer-in-Charge, without breaking out behind the reinforcement.

2) Cleaning of Concrete and Rebar

Remove loose particles and dust using high pressure water or vacuum cleaner. Concrete surfaces to be bonded must be free from dirt, oil, grease, asphalt etc. Corrosion must be removed before placing the new concrete. If deterioration is due to chloride contamination or if the reinforcement is covered with loose corrosion elements having pits, use water abrasive blasting until all the rust is removed

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Spalling, Abnormal Anchorage</b>	<b>PLATE 3-3</b>
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<b>Remedial Measure</b>	<b>Hand applied Mortar (A) &amp; (B)</b>
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The concrete surfaces selected for repair shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss, and then coated by bonding primer. Utmost care shall be taken to ensure that vibration generated during the process does not cause delamination of adjacent render or concrete.

### 3) Additional concrete breakout

Where the breakout indicates that the exposed reinforcement is further corroded or the surrounding concrete is not sound, an enlarged area shall be agreed to be broken to the satisfaction of the Engineer-in-Charge.

The Contractor shall test the concrete for extent of carbonation at the reinforcement depth at his own expense. The depth of breakout in clearly defined areas can be increased based on written instructions from the Engineer-in-Charge, in order to remove all carbonated concrete. The additional concrete breakout shall not extend more than 20 mm behind the bottom layer main reinforcement. During breakout, utmost care shall be undertaken to minimize damage to the existing reinforcement.

### 4) Additional or replacement rebar

The Contractor shall report to the Engineer any rebar which has 10% or more section loss as a result of corrosion. Additional or replacement rebar shall be provided as instructed by the Engineer. Replacement rebar shall be cleaned to the same standard as the existing rebar. This replacement rebar shall be lapped on the side of the existing bars and be spot welded on one side. It shall be fixed along its length at suitable intervals to prevent sagging. The corroded rebars shall be cleaned and applied with zinc rich primer to prevent further corrosion. The Contractor shall obtain Engineer's approval for the rebar coating prior to proceeding with repair mortar application.

### 5) Bonding coating to concrete and rebar

Epoxy bonding coats are applied to dry and clean concrete surfaces in order to bond firmly. Specially formulated resins are also available for damp surfaces. Apply the selected bonding coat to steel bars as shown in the photo; with a brush working vigorously to ensure that they are evenly covered all around.

**Epoxy bonding coat**



### 6) Filling up repair material

The mortar should be placed in layers of about 20 mm thickness. Compact each layer thoroughly over the entire surface using a wooden trowel or hammer.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Spalling, Abnormal Anchorage</b>	<b>PLATE 3-3</b>
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<b>Remedial Measure</b>	<b>Hand applied Mortar (A) &amp; (B)</b>
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Generally, there should be no time delays between the placing and compacting of layers. The patching to the surrounding concrete is performed using a form material, and then hammered using a mallet, wood float or steel trowel.

The mortar shall be mixed using equipment (normally a force action mixer) approved by the Engineer.

The mixing liquid shall be added to the dry components and thoroughly mixed to achieve a uniform consistency, unless otherwise approved by the Engineer. The mortar shall then be applied to the bonding agent using hand packing and trowel to the satisfaction of the Engineer-in-Charge. The textured finish of the final repair mortar layer shall match the finish on the existing interior surface.

The repair mortar application shall be built up to the original surface profile in layers not exceeding 20 mm and the final layer shall not exceed 15 mm, unless otherwise recommended by the manufacturer and approved by the Engineer-in-Charge. The Engineer may approve repair mortar application thickness of up to 50 mm for lightweight mortars, provided the repair mortar manufacturer can furnish a technical data to justify a layer thickness of greater than 20 mm.

**Filling up in Patching**



### 7) Curing

All types of cement repairs need thorough and continuous curing to develop strength and impermeability, and to minimize drying shrinkage while bond strength is developing. Curing of the repair mortar shall be in accordance with the polymer modified additive manufacturer's instructions.

Where curing agents are specified by the manufacturer, they shall be applied immediately after the surfaces have been scarified for the next repair mortar layer or troweled to a finish.

**Curing after Patching**



**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Spalling, Abnormal Anchorage</b>	<b>PLATE 3-3</b>
<b>Remedial Measure</b>	<b>Hand applied Mortar (A) &amp; (B)</b>	

**6. Method of Measurement and Payment**

**6-1 Method of Measurement**

The Engineer will measure the area prepared for Hand applied Mortar by the square meter after the identified thickness of surface has been removed. The measured pay quantity will be those areas verified by the Engineer and marked as unsound or delaminated concrete.

**6-2 Basis of Payment**

The price and payment per square meter of Hand applied Mortar shall include full compensation for removal of deteriorated concrete, surface cleaning and preparation, furnishing and placing all materials, labor, equipment, tools. It shall also include construction and removal of formworks and other temporary works necessary to complete the patching works.

Pay Item No.	Name	Unit of Measurement
3-3-1	Hand applied Mortar (A)	Square Meter (m <sup>2</sup> )
3-3-2	Hand applied Mortar (B)	Square Mater (m <sup>2</sup> )

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Delamination, Spalling</b>	<b>PLATE 3-4</b>
<b>Remedial Measure</b>	<b>Spray applied mortar</b>	

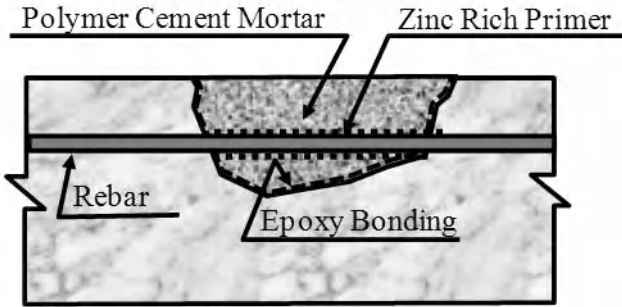
**1. Work description**

Spray applied mortar repair is performed to restore large areas where sound concrete is damaged by delamination, spalling, and/or scaling. This repair mortar is generally applied using special spray equipment and requires no formworks. Each spray thickness is limited to a maximum of 30 mm depth.

Spray applied mortar repair is applied to the vertical and horizontal concrete surfaces, even for under deck surface repair. Spray applied mortar is for defects with exposed rebars, and reinforcing rebars or mesh is added in many cases (Figure 3-4-1).

Spray applied mortar repairs may be composed of Polymer cement mortars or non-shrinkage cement mortars depending on the type of spraying, location and extent of damage.

**Figure 3-4-1 Spray applied Mortar**



**2. Application Criteria**

Spray applied mortar is for surfaces with exposed rebars, with large defective widths over 600 mm, and up to 100 mm depths.

To keep good bond ability to the existing concrete, Polymer cement mortar is applied in Spray applied mortar.



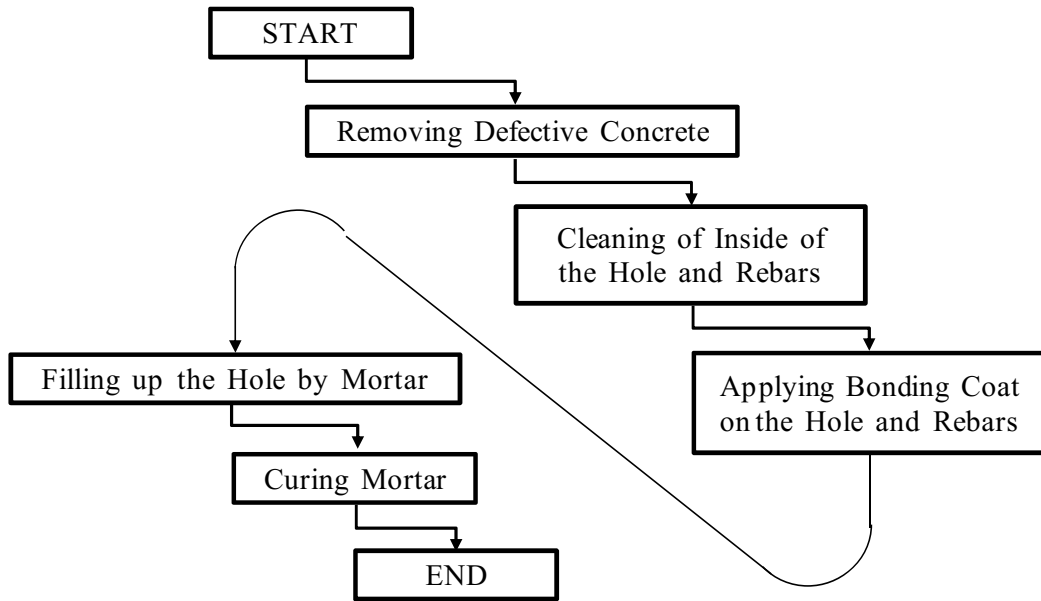
**3. Work sequence**

Work sequence of Spray applied mortar is shown in Figure 3-4-2.

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Delamination, Spalling</b>	<b>PLATE 3-4</b>
<b>Remedial Measure</b>	<b>Spray applied mortar</b>	

**Figure 3-4-2 Work sequence**



**4. Required tools/equipment and material**

1) Tools/Equipment

Spray applied mortar:

- Power Disc Grinder
- Portable Generator
- Spray equipment with pump

2) Material

Spray applied Mortar

- Polymer Cement
- Epoxy Bonding Coat
- Zinc Rich Primer

**5. Requirement, Specifications**

5-1 Material

Material shall be approved by the Engineer through mill certificate of the supplier.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Delamination, Spalling</b>	<b>PLATE 3-4</b>
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<b>Remedial Measure</b>	<b>Spray applied mortar</b>
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Polymer cement mortar shall conform to the requirements of the specifications shown in Table 3-4-1 or equivalent ASTM Specifications.

Property	Test Method	Unit	Specification
Thermal Expansion	ASTM C531	mm/mm°C	2.0 x 10 <sup>-5</sup>
Slant Shear Bond to Concrete	ASTM C882	N/mm <sup>2</sup>	1.5 /above
Compressive Strength (7days x 20°C)	ASTM C579	N/mm <sup>2</sup>	20 /above

### 2) Corrosion Protective Coating

The Protective Coating of rebar shall conform with the requirements of the specifications in Table 3-4-2.

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	75
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	40
Tensile Strength	ASTM D638M	N/mm <sup>2</sup>	30
Tensile Shear Bond to Steel	ASTM D1002	N/mm <sup>2</sup>	10
Slant Shear Bond to Mortar	ASTM C882	N/mm <sup>2</sup>	15

### 3) Zinc Rich Primer

The zinc rich primer to rebar shall be in accordance with the requirements of the specifications in Table 3-4-3.

Property	Test Method	Unit	Specifications
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 Film Test	-	%	87.5 ± 2

### 5-2 Work requirement

The Contractor shall submit the Methodology (Procedures) to the Engineer-in-Charge for his review and approval before commencement of the work.

## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Delamination, Spalling**

**PLATE 3-4**

**Remedial Measure**

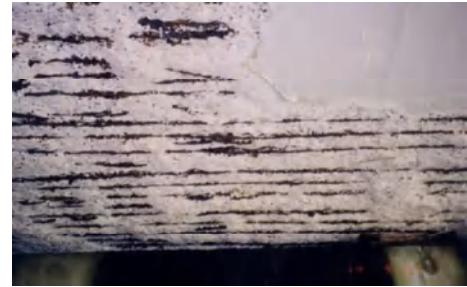
**Spray applied mortar**

1) Removal of defective concrete

Remove all defective, unsound and contaminated concrete by jet water and prepare the edges for the spray area as shown in the attached photo.

If local corrosion in reinforcement with section loss is found, which would require additional rebar.

**Removal of defect concrete**



**Cleaning of Concrete and Rebar**



Concrete within marked out areas shall be removed using jet water or hammer and chisel, the exposed reinforcement shall be cut and the sound of concrete substrate shall be determined to the satisfaction of the Engineer-in-Charge, without breaking out behind the reinforcement.

2) Cleaning of Concrete and Rebar

Remove loose particles and dust using high pressure water or vacuum cleaner. Concrete surfaces to be bonded must be free from dirt, oil, grease, asphalt etc. Corrosion must be removed before placing the new concrete.

If deterioration is due to chloride contamination or if the reinforcement is covered with loose corrosion elements having pits, use water abrasive blasting until all the rust is removed.

## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Delamination, Spalling**

**PLATE 3-4**

**Remedial Measure**

**Spray applied mortar**

The concrete surfaces selected for repair shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss, and then coated by bonding primer. Utmost care shall be taken to ensure that vibration generated during the process does not cause delamination of adjacent render or concrete.

### 3) Additional concrete breakout

Where the breakout indicates that the exposed reinforcement is further corroded or the surrounding concrete is not sound, an enlarged area shall be agreed to be broken to the satisfaction of the Engineer-in-Charge.

The Contractor shall test the concrete for extent of carbonation at the reinforcement depth at his own expense. The depth of breakout in clearly defined areas can be increased based on written instructions from the Engineer-in-Charge, in order to remove all carbonated concrete. The additional concrete breakout shall not extend more than 20 mm behind the bottom layer main reinforcement. During breakout, utmost care shall be undertaken to minimize damage to the existing reinforcement.

### 4) Additional or replacement rebar

The Contractor shall report to the Engineer any rebar which has 10% or more section loss as a result of corrosion. Additional or replacement rebar shall be provided as instructed by the Engineer. Replacement rebar shall be cleaned to the same standard as the existing rebar. This replacement rebar shall be lapped on the side of the existing bars and be spot welded on one side. It shall be fixed along its length at suitable intervals to prevent sagging. The corroded rebars shall be cleaned and applied with zinc rich primer to prevent further corrosion. The Contractor shall obtain Engineer's approval for the rebar coating prior to proceeding with repair mortar application.

The mortar should be placed in layers of about 20 -40 mm thickness. Compact each layer thoroughly over the entire surface using a wooden trowel or hammer.

#### Additional epoxy coated Rebar



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Delamination, Spalling</b>	<b>PLATE 3-4</b>
<b>Remedial Measure</b>	<b>Spray applied mortar</b>	

### 5) Bonding coating to concrete and rebar

Epoxy bonding coats are applied to dry and clean concrete surfaces in order to bond firmly. Specially formulated resins are also available for damp surfaces. Apply the selected bonding coat to steel bars as shown in the photo; with a brush working vigorously to ensure that they are evenly finished.

**Epoxy bonding coat**



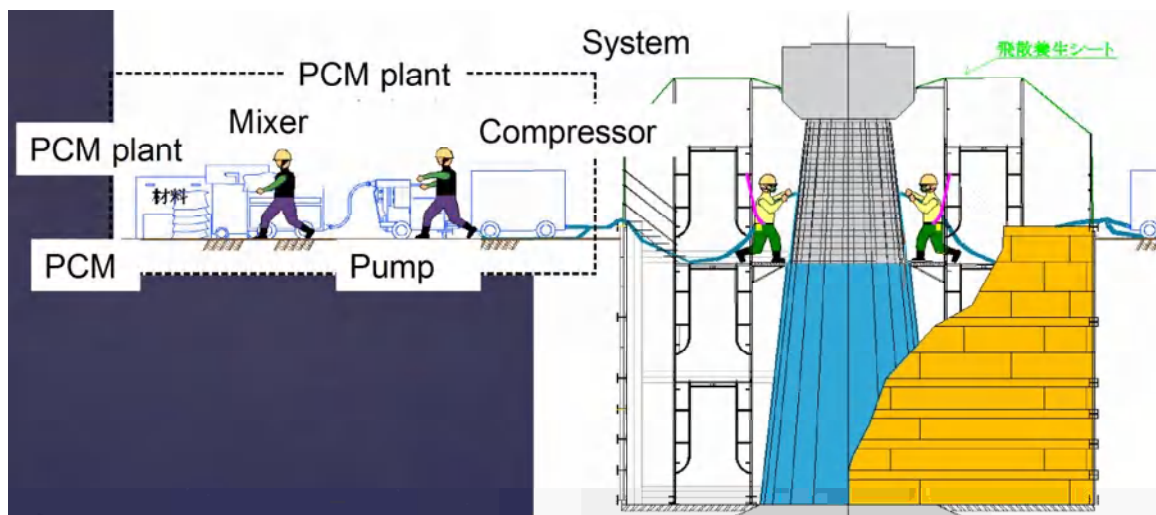
### 6) Spraying repair material

The spray mortar (Polymer Cement Mortar) should be placed in layers of about 20-40 mm thickness. Spray personal should be trained specialist. The mortar (PCM) shall be mixed and sprayed using special equipment approved by the Engineer.

**Spraying repair mortar**



**Spraying repair mortar system**



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Delamination, Spalling</b>	<b>PLATE 3-4</b>
<b>Remedial Measure</b>	<b>Spray applied mortar</b>	

The mixing liquid shall be added to the dry components and thoroughly mixed to achieve a uniform consistency, unless otherwise approved by the Engineer. The mortar shall then be pumped to spray nozzle and applied to the repair area to the satisfaction of the Engineer-in-Charge. The textured finish of the final repair mortar layer shall match the finish on the existing interior surface.

The repair mortar application shall be built up to the original surface profile in layers not exceeding 20 mm and the final layer shall not exceed 15 mm, unless otherwise recommended by the manufacturer and approved by the Engineer-in-Charge.

### 7) Curing

All types of cement repairs need thorough and continuous curing to develop strength and impermeability, and to minimize drying shrinkage while bond strength is developing. Curing of the repair mortar shall be in accordance with the polymer modified additive manufacturer's instructions.

Where curing agents are specified by the manufacturer, they shall be applied immediately after the surfaces have been scarified for the next repair mortar layer or troweled to a finish.

### Curing after Spraying



<b>MAJOR REPAIR METHODS</b>								
<b>Defect/Deficiency</b>	<b>Delamination, Spalling</b>	<b>PLATE 3-4</b>						
<b>Remedial Measure</b>	<b>Spray applied mortar</b>							
<b>6. Method of Measurement and Payment</b>								
<p>6-1 Method of Measurement</p> <p>The Engineer will measure the area prepared for Spray applied Mortar by the square meter after the identified thickness of surface has been removed. The measured pay quantity will be those areas verified by the Engineer and marked as unsound or delaminated concrete.</p> <p>6-2 Basis of Payment</p> <p>The price and payment per square meter of Spray applied Mortar shall include full compensation for removal of deteriorated concrete, surface cleaning and preparation, furnishing and placing all materials, labor, equipment, tools. It shall also include construction of spray system and other temporary works necessary to complete the spray works.</p> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left; border-bottom: 1px solid black;">Pay Item No.</th> <th style="text-align: left; border-bottom: 1px solid black;">Name</th> <th style="text-align: left; border-bottom: 1px solid black;">Unit of Measurement</th> </tr> </thead> <tbody> <tr> <td style="border-top: 1px solid black;">3-4</td> <td style="border-top: 1px solid black;">Spray applied Mortar</td> <td style="border-top: 1px solid black;">Square Meter (m<sup>2</sup>)</td> </tr> </tbody> </table>			Pay Item No.	Name	Unit of Measurement	3-4	Spray applied Mortar	Square Meter (m <sup>2</sup> )
Pay Item No.	Name	Unit of Measurement						
3-4	Spray applied Mortar	Square Meter (m <sup>2</sup> )						

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence</b>	<b>PLATE 3-5</b>
<b>Remedial Measure</b>	<b>Fluid Recasting Mortar/Concrete</b>	

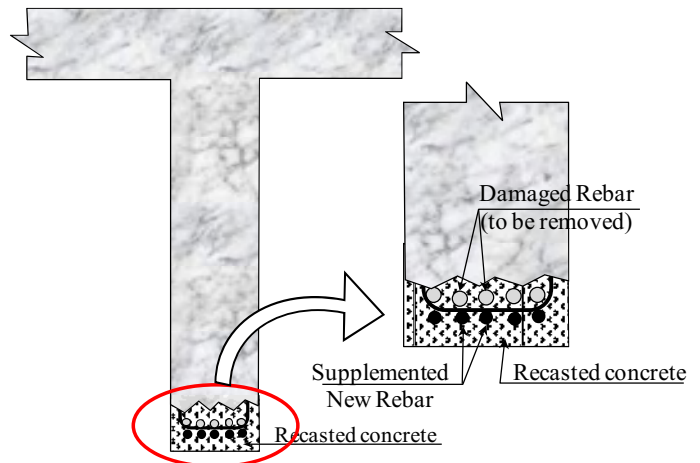
**1. Work description**

Recasting method, which involves casting of the damaged area, by placing concrete or grouting mortar on the formwork, is usually most suitable for severely damaged concrete, or for largely damaged areas with densely-spaced rebar as shown in Figure 3-5-1. If concrete placing by vibration is often a problem, grout and free flowing self-compacting concrete should be adopted to minimize the vibration required. Typical damage with heavily rusted rebar is as shown below Photo.

**Typical Damage**



**Figure 3-5-1 Recasting Mortar/Concrete**



**2. Application Criteria**

Recasting Concrete/Grout is divided into two methods namely, **Concrete Placing** and **Mortar Grouting**. Further, the Mortar Grouting has two categories depending on materials used, i.e., Portland cement and Non-Shrink Cement.

Considering the damaged position, scale of damage, formwork shape and density of rebar, the application of the recasting material such as concrete and grout shall be selected.

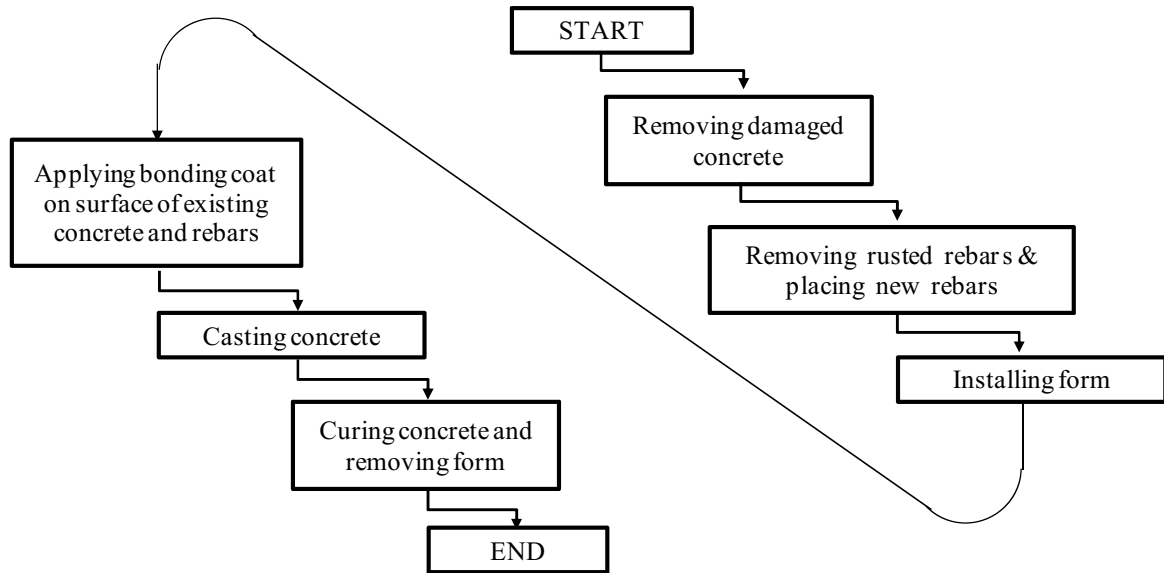
**3. Work sequence**

Work sequence of Recasting Mortar/Concrete is as shown Figure 3-5-2.

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence</b>	<b>PLATE 3-5</b>
<b>Remedial Measure</b>	<b>Fluid Recasting Mortar/Concrete</b>	

**Figure 3-5-2 Work sequence**



**4. Required Equipment/Tools and Material**

**4-1 Tools/Equipment**

The following Tools/Equipment are necessary for the Recasting Mortar/Concrete.

- Sawing Equipment
- High Pressure Water Blasting
- Handy Concrete Breaker or jackhammer
- Handy power Chisel
- Concrete Mixer 30 liters
- Mortar Mixer with Pump (For Mortar)
- Vibrator
- Troweling tools

**4-2 Material**

The following Materials are necessary for the Recasting Mortar/Concrete.

➤ For Concrete

- Portland Cement
- Silica fume
- Aggregate/Sand
- Rebar
- Epoxy Resin Adhesive (Bonding coat)
- Anti-corrosion Primer to Rebar (Zinc Rich Primer)
- Cotton mat (Curing)

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence</b>	<b>PLATE 3-5</b>
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<b>Remedial Measure</b>	<b>Fluid Recasting Mortar/Concrete</b>
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➤ For Mortar

- Portland Cement (Cement Mortar)
- Silica fume
- Sand
- Reinforcing steel bar
- Epoxy Resin Adhesive (Bonding coat)
- Anti-corrosion Primer to Rebar (Zinc Rich Primer)

### 5. Requirement, Specifications

#### 5-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier

1) Concrete mixture

The actual mix portion shall be determined during a field mixture test and approved by the Engineer. These quantities will make about 0.03 cubic meters of concrete and would be fully accommodated in a small mixer.

- a. Cement; Portland cement 13.0 kg with Silica fume 0.5 kg (If Silica fume is unavailable, use 13.5kg cement)
- b. Crushed aggregate; 36.0 kg (10mm down graded)
- c. Sand; 18.5 kg (assumed 2% water content)
- d. Water; 5.4 liters (maximum)
- e. Super plasticizer; 25ml (nominal)

2) Epoxy bonding primer

Epoxy bonding primer shall conform to the Specifications as shown in Table 3-5-1.

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	70
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	40
Tensile Strength	ASTM D638M	N/mm <sup>2</sup>	30
Tensile Shear Bond to Steel	ASTM D1002	N/mm <sup>2</sup>	10
Slant Shear Bond to Mortar	ASTM C882	N/mm <sup>2</sup>	15

3) Zinc rich primer

The Zinc-rich primer applied to rebar shall be in accordance with the specifications shown in Table 3-5-2, or equivalent ASTM Specifications.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence</b>	<b>PLATE 3-5</b>
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<b>Remedial Measure</b>	<b>Fluid Recasting Mortar/Concrete</b>
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**Table 3-5-2 Specifications for Zinc Rich Primer**

Property	Test Method	Unit	Specifications
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 Film Test		%	87.5 ± 2

### 5-2 Work requirement

The Contractor shall submit the Methodology Procedure of the Work to the Engineer for his review and approval before commencement of the work.

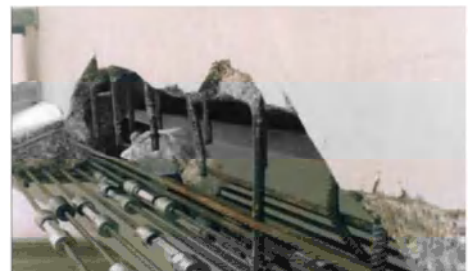
#### 1) Removal of damaged concrete

Old concrete shall be removed as approved by the Engineer for all the areas determined to be defective. Saw cuts shall be made on the surface of concrete. Concrete saw shall be used to provide vertical edges with approximately 20 mm depth around the perimeter to be replaced. Girder concrete is removed by breaker and portable electric chisel near the vertical edges.



#### 2) Removing rusted rebar and supplying new rebar

Any damage to the rebar to remain in place shall be repaired or replaced to the satisfaction of the Engineer at the Contractor's expense. All existing rebar shall remain in place except those which are significantly corroded.



Deteriorated old rebar which lost 20 percent or more of their original sectional area shall be cut up and be replaced by new reinforcing bars. New bars to be provided shall be of same or bigger diameter than the existing one, considering the current loading condition.

The lap length is calculated as 30 times of the new rebar diameter. The new rebar shall be tied to the existing bars using tie wires.

The new bars shall be coated by zinc rich primer. An approved mechanical bar splice capable of developing in tension at least 3 to 25 percent of the yield strength of the existing bar shall be used when it is not feasible to provide the minimum bar lap.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence</b>	<b>PLATE 3-5</b>
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<b>Remedial Measure</b>	<b>Fluid Recasting Mortar/Concrete</b>
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When replacement of rebar is required, followings shall be taken into consideration:

a) Necessity of scaffoldings

In case all main rebar of the girder is required replacement, installation of scaffoldings is necessary.

Meanwhile, in case of partial replacement of the main rebar of the girder, necessity of the scaffoldings is depending upon stress condition of the girder after removing some of rusted rebar. Examination of stress condition of the girder will be carried out with consideration of load distribution effect by cross beams, traffic restriction and reducing safety factor of remaining rebar.

b) Installation of the scaffoldings

In case installation of the scaffoldings required, requirements of the scaffolding are as follows: (Refer Figure 3-5-3 Example of the Scaffolding structure)

- ✓ Scaffolding member shall be strong enough against imposed load from the girder.
- ✓ Buckling strength of the scaffolding member shall be examined.
- ✓ Stability of the scaffolding system shall be examined.
- ✓ Bearing capacity of a foundation of the scaffolding structure shall be examined. Any settlement of the scaffolding structure will not be allowed. Therefore, the foundation of the scaffolding structure shall be designed carefully.
- ✓ The scaffolding structure shall be remained until strength of new concrete reaches its design strength.

3) Application of bonding coat

The concrete surface 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 substrata 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 and exposed concrete reinforcement. The subsequent coat shall be applied while the previous bond coat is still wet or tacky.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence</b>	<b>PLATE 3-5</b>
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<b>Remedial Measure</b>	<b>Fluid Recasting Mortar/Concrete</b>	
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Rebar rust must be removed before placing the new concrete. If the damage is due to chloride contamination, it is essential to remove all the rust from the rebar, as the residual rust (contaminated with chlorides) could restart the corrosion process at a later stage. The surface of cleaned rebar should be coated with zinc rich paint for protection against future corrosion.

An appropriate type of bonding agent for concrete and reinforcement should be used when the bonding coat is applied to the faces of the old concrete and rebar. Bonding agent shall be selected with consideration of limited working time available for casting concrete.

#### 4) Installation of formwork

The Contractor shall submit the shop drawings of the formwork of recasting concrete prior to the commencement of the repair works for obtaining Engineer's approval. The formwork for re-casting type of repairs must be very rigid and well-supported to prevent the new concrete from sagging away.



It shall also withstand pumping forces if concrete is to be poured into forms. The formwork shall also withstand the forces of clamped-on external vibrators.

Formworks should be provided with slit hoppers and openings where appropriate for placing new concrete or grouting mortar and for inserting poker vibrators. Form-releasing agents to be used should be compatible with the repair materials, particularly Epoxy-based and latex-modified concrete and grouts.

#### 5) Mixing and casting mortar/concrete

A mechanical batch mixer should be used to ensure homogeneity, workability and good board life. Clean, potable water shall be used and the maximum amount added shall be consistent with optimum workability. Hand mixing shall not be permitted unless approved in writing by the Engineer, who should outline hand mixing procedures.



The finished color should not be analyzed until addition and full mixing of the cement materials and water are complete.

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence</b>	<b>PLATE 3-5</b>
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<b>Remedial Measure</b>	<b>Fluid Recasting Mortar/Concrete</b>
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All large damaged areas shall be re-cast to accurately restore the original face of the member.

Concrete/cement mortar shall be pumped through the pour access holes. Spacing for pour access holes shall not exceed 600 mm. Vibrators, placed on the outside face of the formwork, shall be used to achieve proper consolidation. The maximum time allowed between the delivery of grout to the site and the grouting process shall not exceed 60 minutes.



6) Curing and protection

Continuous water cure with spray-water is always preferable as membrane cure, which helps slow down drying process.

Formworks for load bearing structural members shall remain in position until at least 80% of the 28 day compressive strength of the new concrete is achieved and approved by the Engineer.



7) Field Test

Compression tests and fabrication of specimens for cement grout will be performed as specified in ASTM C 109, at intervals selected by the Engineer during construction. A set of three specimens will be tested for 1 day, 7 days, 28 days, and additional time period as appropriate.

**6. Measurement and Payment**

6-1 Method of Measurement

Recasting mortar/concrete performed in accordance with the plans and this specification will be measured in cubic meters. The quantity to be paid for will be the number of cubic meters of concrete replaced on the girder and accepted by the Engineer. The measurement made for rebars will be in Kilograms.

6-2 Basis of Payment

The quantity, measured as prescribed above, shall be paid for at the contract unit price. Removal and disposal of existing rebar and furnishing and installing new rebar will be paid

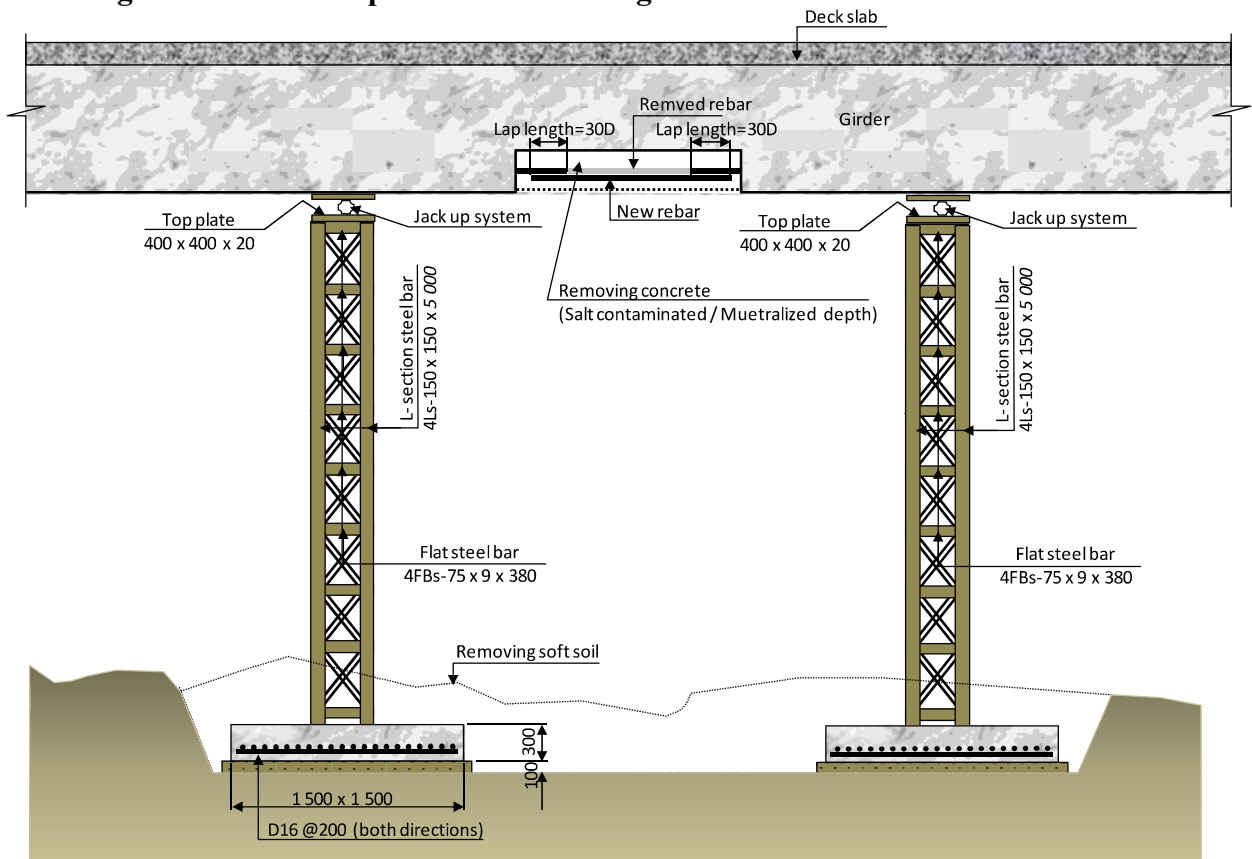
## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence</b>	<b>PLATE 3-5</b>
<b>Remedial Measure</b>	<b>Fluid Recasting Mortar/Concrete</b>	

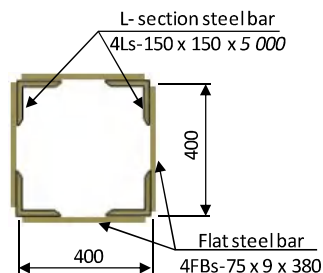
for at the contract unit price. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related necessary works for supporting the deck slab and girders and scaffolding as detailed in the plans and specified herein.

Pay Item No.	Name	Unit of Measurement
3-5-1	Recasting Concrete	Cubic Meter (m <sup>3</sup> )
3-5-2	Recasting Mortar	Cubic Meter (m <sup>3</sup> )
3-5-3	Replaced rebar	Kilogram (kg)

**Figure 3-5-3 Example of the scaffolding structure**



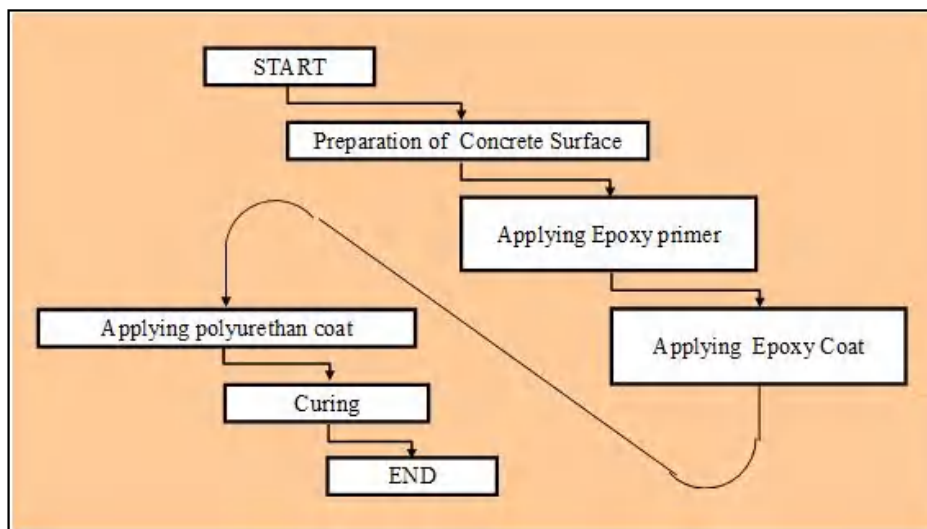
**Figure 3-5-4 Cross section of the scaffolding structure**



<b>MAJOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Crack on concrete, Chloride Deterioration</b>	<b>PLATE 3-6</b>
<b>Remedial Measure</b>	<b>Protective coating</b>	
<b>1. Work description</b>		
<p>Protective coating is the simplest and most effective preventive maintenance in the coastal region against chloride attack. It is recommended to take flexible epoxy-based coating suitable for active cracks and those subject to movement due to applied loads and temperature changes.</p> <p>The purpose of the Epoxy coating is to prevent water from reaching the reinforcing steel, development of hydrostatic pressure within the crack, staining of concrete surface and causing moisture problems on the far side of the crack.</p> <p>Epoxy coating is suitable for repair of vertical or overhead cracks, with widths of less than 0.3 mm.</p> <p>Epoxy coating, made up of epoxy compounds with high strength and non-solvent two-component material, is characterized by its excellent adhesion to both dry and wet concrete.</p> <p>It should be noted that epoxy coating is not a repair method, but a protective or preventive application to prolong the bridge service life. The coating, applied using a roller brush, should be capable of penetrating overhead, downward and vertical. This measure is one of the most appropriate routine maintenance activities.</p>		
<b>2. Application criteria</b>		
<p>As a protective or preventive measure, epoxy coating should be applied on surfaces of concrete structures, with cracks of less than 0.3 mm width, regardless of whether a crack formation is structural or non-structural. Subsequently, the district office should regularly monitor the cracks for future repair, if necessary.</p>		
<b>3. Work sequence</b>		
<p>Work sequence of Protective Coating is as shown Figure 3-6-1.</p>		

MAJOR REPAIR METHODS		
Defect/Deficiency	Crack on concrete, Chloride Deterioration	PLATE 3-6
Remedial Measure	Protective coating	

Figure 3-6-1 Work sequence



4.1 Equipment/Tool **4. Required Equipment/Tool and Material**

Following equipment/tool is necessary for Protective Coating:

- Paint brush or Paint roller

4.2 Material

- Epoxy Plimer and Epoxy Coat
- Polyurethan Coat

**5. Requirement, Specification**

5-1 Material

The epoxy material shall conform to the requirements of the specifications in Table 3-6-1.

**Table 3-6-1 Specification of Epoxy Material for Coating**

Property	Test Method	Unit	Specification
Viscosity	ASTMD2393	mPa.s	500 below
Bond Strength to Concrete Dry / Wet	ASTM D7234	N/mm <sup>2</sup>	1.5
Slant Shear Bond Strength	ASTM C882	N/mm <sup>2</sup>	15

The material shall be approved by the Engineer through mill certificate of the supplier.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on concrete, Chloride Deterioration</b>	<b>PLATE 3-6</b>
<b>Remedial Measure</b>	<b>Protective coating</b>	

### 5-2 Work requirement

#### 1) Preparation of Concrete Surface

Depending upon conditions of the concrete one or more methods of surface preparation may be required. It is common for decontamination to precede mechanical preparation, and if necessary a second decontamination to follow.

The preferred methods for creation of a surface profile, including the removal of dirt, dust, laitance and curing compounds, is steel shotblasting, abrasive (sand) blasting or scarifying. Vertical and overhead surfaces, such as cove base, wall, and ceiling surfaces shall be prepared utilizing methods of grinding, scarifying, abrasive (sand) blasting, needle scaling, high pressure water jetting (5,000 to 45,000 psi), or vertical steel shotblasting.

#### 2) Application of protective coating

Apply protective coating to concrete surfaces as recommended by NLIM Japan bellow.

**Tab. 3-6-2 Protective Coating by NLIM jp**

Items	Thickness	Usage kg/m <sup>2</sup>		remark
Epoxy primer		0.1	brush,roller	over 16 hour
Epoxy putty		0.5	brush,roller	over 16 hour
flexible Epoxy coat	160 μm	0.35	brush,roller	over 16 hour
flexible polyurethan coat	30μm	0.12	brush,roller	

The epoxy putty is used for leveling of concrete surface.

The purpose of use of polyurethane coat is the protection against sun shine etc.

#### 3) Curing

After application, perform until the protective coating hardens.

MAJOR REPAIR METHODS		
Defect/Deficiency	Crack on concrete, Chloride Deterioration	PLATE 3-6
Remedial Measure	Protective coating	

**6. Measurement and Payment**

6-1 Method of Measurement

Protective coating performed in accordance with the plans and this specification will be measured in square meters. The quantity to be paid for includes the cleaning and full protective work of applied concrete surface in square meters, accepted by the Engineer.

6-2 Basis of Payment

The quantity measured as prescribed above, shall be paid for at the contract unit price. This also includes performing all the works involved in preparing the surfaces of existing concrete and application of protective coating, as specified on plans and specifications, and as directed by the engineer.

Pay Item No.	Name	Unit of Measurement
3-6	Protective Coating	Square Meter (m <sup>2</sup> )

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Fallen out of Deck slab</b>	<b>PLATE 3-7</b>
<b>Remedial Measure</b>	<b>Partial Replacement of Deck slab</b>	

### 1. Work description

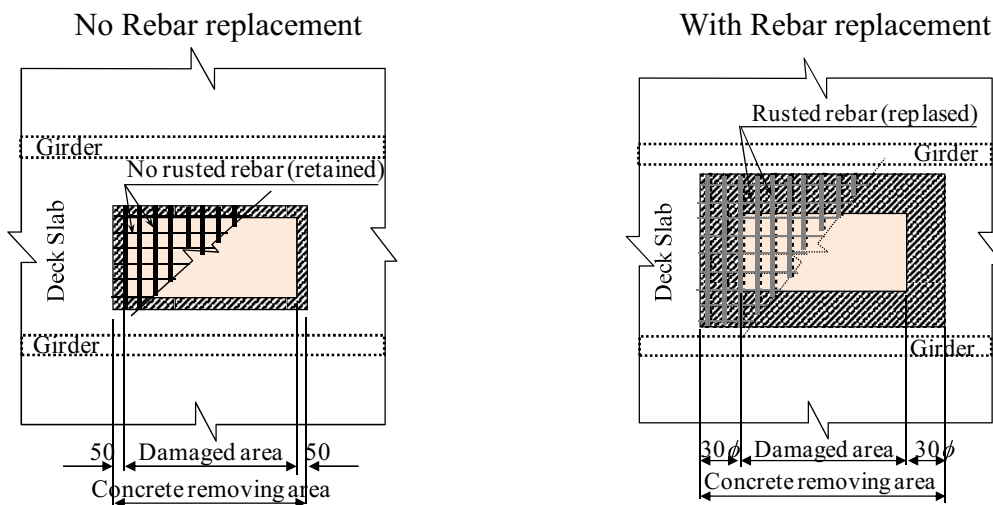
Partial replacement of slab is carried out to replace portion of the concrete that has been severely damaged. If damaged portion is not removed, as shown in Photo 6-1, further deterioration is expected, which could impair the strength, stability and serviceability of the structure. The cause of such damage could be corrosion of reinforcement, fracturing, spalling, delamination, honeycomb or water leakage.

Recasting generally involves removal of the deteriorated concrete, cleaning up the substrate and reinforcement, setting up formwork and placement of new concrete as shown in Photo below, Figure 3-7-1 and Figure 3-7-2.

**Damaged Deck Slab with water leakage**



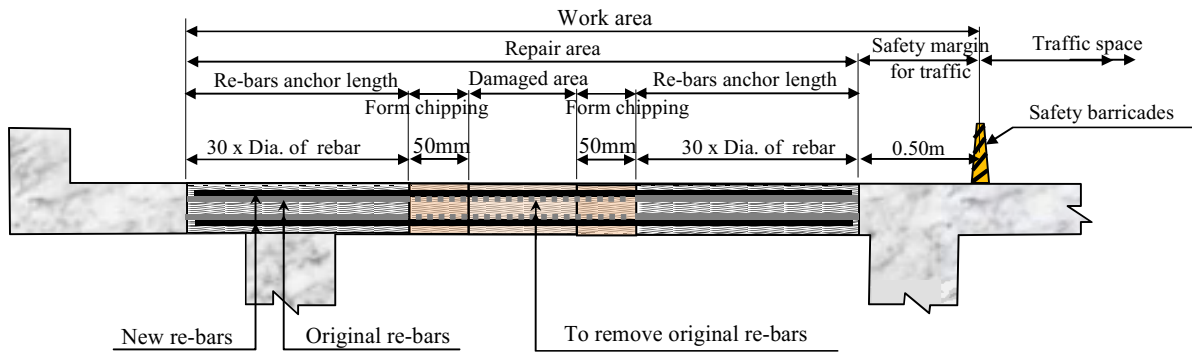
**Figure 3-7-1 Partial Replacement of Deck Slab**



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Fallen out of Deck slab</b>	<b>PLATE 3-7</b>
<b>Remedial Measure</b>	<b>Partial Replacement of Deck slab</b>	

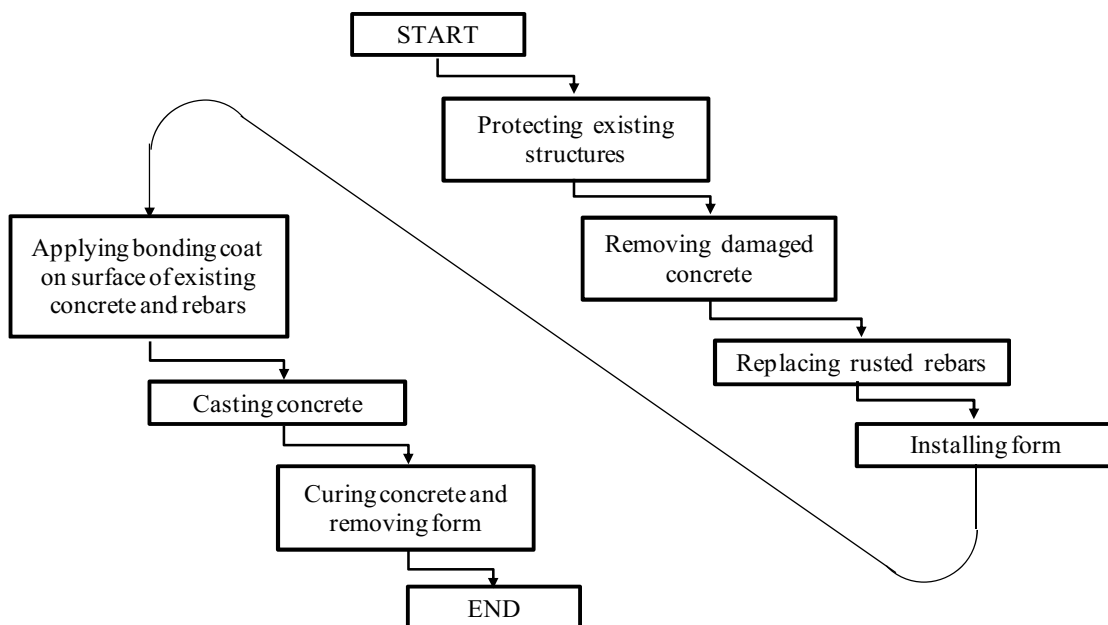
**Figure 3-7-2 Partial Replacement of Concrete with Rebar Replacement**



### 2. Work sequence

Work sequence of Partial Replacement of Deck Slab is as shown in Figure 3-7-3.

**Figure 3-7-3 Work sequence**



### 3. Required Equipment/Tool and Material

#### 3-1 Equipment/Tool

Following Equipment/Tool are necessary for the work.

- Sawing equipment


**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Fallen out of Deck slab</b>	<b>PLATE 3-7</b>
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<b>Remedial Measure</b>	<b>Partial Replacement of Deck slab</b>	
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<p>3-2 Materials</p>	<ul style="list-style-type: none"> <li>-High pressure water blasting</li> <li>-Handy concrete breaker or jack hammer</li> <li>-Handy power chisel</li> <li>-Concrete mixer 30 liters</li> <li>-Vibrator</li> <li>-Troweling tools</li> </ul> <ul style="list-style-type: none"> <li>-Portland cement</li> <li>-Silica fume</li> <li>-Rebar</li> <li>-Epoxy Resin (Bonding coat to concrete)</li> <li>-Zinc rich primer (Bonding coat to rebar)</li> </ul>	
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**4. Requirement, Specification**

<p>4-1 Work requirement</p> <p>The Contractor shall submit the Methodology (procedures) of the Work to the Engineer for his review and approval before the work commences.</p> <p>1) Protection of existing structure</p> <p>The existing structure shall be properly supported to safeguard against instability and deformation during the repair work.</p> <p>2) Removal of concrete</p> <p>All deteriorated or damaged concrete surfaces are cut by saw, forming vertical edges, and then removed using breaker and chisel. Rebars are examined for loss of section due to corrosion. If cross sectional area of the reinforcement has reduced by more than 20%, additional reinforcement is required and necessary.</p> <p>Concrete areas subjected for full-depth repair shall be removed, as determined by the Engineer. While, for partial depth repair it, should extend below half the concrete deck thickness. Saw cuts shall be made on the perimeter of the deck to be replaced. Concrete saw shall then be used to form vertical edges, with approximately 20 mm deep, around the defined perimeter. Deck slab concrete is removed using a breaker while hand power chisel is used near the vertical edges.</p>	
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## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Fallen out of Deck slab</b>	<b>PLATE 3-7</b>
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<b>Remedial Measure</b>	<b>Partial Replacement of Deck slab</b>
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3) Rebar replacement

Any damage to the rebars to remain in place shall be repaired or replaced to the satisfaction of the Engineer at the Contractor's expense. All existing rebars shall remain in place except those which are significantly corroded.

Deteriorated old rebars which have lost 20 percent or more of their original sectional area shall be cut up and be replaced by new reinforcing bars. New bars to be provided shall be of the same or bigger diameter than the existing, considering the current loading condition.

The lap length is calculated as 30 times of the new rebar diameter. The new rebar shall be tied to the existing bars using tie wires.

The new bars shall be coated by zinc-rich primer. An approved mechanical bar splice capable of developing in tension at least 3-25 percent of the yield strength of the existing bar shall be used when it is not feasible to provide the minimum bar lap.

4) Installation of form

Soffit formwork for recasting deck slab must be very rigid and well-supported to prevent the new concrete from sagging to the old concrete, due to its own weight.



5) Application of bonding coat

The concrete surface to which the bond 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 repair mortar. The wetting period will depend upon the substrata condition and the bond coat manufacturer's recommendations, subject to Engineer's satisfaction.



The surface shall then be left wet until the free water has evaporated before the bond coat is applied. The bond coat shall be applied to the exposed concrete surface and also to the exposed reinforcement using a brush. The subsequent repair material shall be applied while the bond coat is still wet or tacky.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Fallen out of Deck slab</b>	<b>PLATE 3-7</b>
<b>Remedial Measure</b>	<b>Partial Replacement of Deck slab</b>	

Rebar rust must be removed before placing the new concrete. If the damage is due to chloride contamination, it is essential to remove all the rust from the rebar, as any residual rust will be contaminated with chlorides which could restart the corrosion process at a later stage. The surface of cleaned rebar should be coated with zinc-rich paint for protection against future corrosion.

A suitable bonding agent for concrete and reinforcement should be applied as the bonding coat to the faces of the old concrete and rebars. Bonding agent shall be selected with consideration of limited working time available for casting concrete.

### 6) Mixing concrete

The concrete mix used for partial replacement of slab concrete must be capable of producing highly impermeable concrete with adequate workability and low shrinkage. The repair mix should be ideally made with the same type of aggregate as the original concrete to minimize thermal stress. It is also usually necessary to use a smaller (20mm) maximum aggregate size for repairs because the space for placing concrete is often restricted. Care should be taken to ensure that aggregate will not react with alkali from the cement particularly as rich mix will be used.

The water cement ratio should not exceed 0.4 to minimize stresses caused by drying shrinkage. In some situations, it may be helpful to add shrinkage-compensating admixtures to the mix. These admixtures work by causing slight expansion to offset shrinkage and thermal contraction.

The fresh concrete should have high cement-paste content for proper bonding with the old concrete and reinforcement. It should also provide high alkalinity for the protection of steel. The mix should have a minimum cement content of 410 kg per cubic meter of concrete. The grading of aggregate and sand must be properly selected to produce a dense concrete and to keep bleeding to an absolute minimum, especially for soffit repairs where bleeding can lead to complete separation between old and new concrete. For small repair jobs concrete may be mixed at site, using a small concrete mixer. On site batching should be avoided. It is preferable to make trial mixes and then pre-batch into convenient sized bags off site with only specified quantities of water and super plasticizer to be added at site. All materials must be weighed by batches.

An assumed mix design for small scale repairs is given below as reference. These quantities will make about 0.03 cubic meter of concrete and could be accommodated in a small mixer.

Example of Mix design for small scale repair work (Reference)

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Fallen out of Deck slab</b>	<b>PLATE 3-7</b>
<b>Remedial Measure</b>	<b>Partial Replacement of Deck slab</b>	

- Cement
  - Portland cement 13.0 kg
  - Silica fume 0.5 kg (If silica fume is unavailable, use 13.5kg cement)
- 10mm Crushed Aggregate 36.0 kg
- Sand (assumed with 2% water content) 18.5 kg
- Water (maximum) 5.4 liters
- Super plasticizer (nominal) 25ml

### 7) Casting concrete

Concrete is placed in the soffit formworks through a suitable method and compacted well using internal or external vibrators. Level the newly cast concrete surfaces by wood float, steel trowel and broom to match the adjacent existing one.



## 5. Measurement and Payment

### 5-1 Method of measurement

Partial deck slab replacement performed in accordance with the plans and the specifications will be measured in cubic meters. The quantity to be paid for includes the replaced concrete on the deck slab in cubic meters, accepted by the Engineer. The basis of measurement for rebars will be in kilogram.

### 5-2 Basis of payment

The quantity, measured as prescribed above, shall be paid for at a contract unit price. Removal and disposal of existing rebars and furnishing and installing new rebars will be paid for at a contract unit price. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related necessary works for supporting the deck slab and girders and scaffolding as detailed in the plans and specifications.

Pay Item No.	Name	Unit of Measurement
3-7-1	Recasting Concrete	Cubic Meter (m <sup>3</sup> )
3-7-2	Replacing Rebar	Kilogram (kg)

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Crack on Deck Slab, Efflorescence</b>	<b>PLATE 3-8</b>
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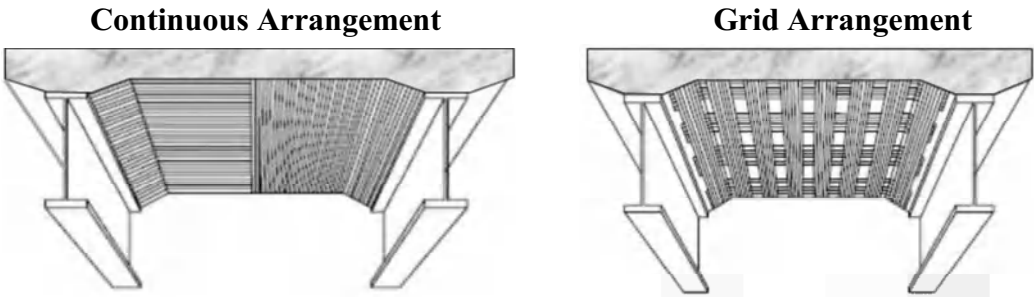
<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>
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**1. Work description**

Carbon fiber sheet for reinforced concrete repairs and strengthening systems consists of a combination of carbon fiber reinforcing material and adhesive resin such as epoxies and other materials. This composite product is intended to enhance the capacity of the concrete deck slab and extend its service life. The function of the resin is to serve as an adhesive bond onto the concrete surface and facilitate the transfer of stresses to and from the carbon fiber sheet.

The works shall consist of furnishing and installing two types of Carbon Fiber Sheets as shown in Figure 3-8-1 for concrete strengthening systems in accordance with the plans and specifications. The systems shall be designed to strengthen and stiffen concrete bridge deck slab and tested by the Engineer to verify performance.

**Figure 3-8-1 Arrangement of Carbon Fiber Sheet**



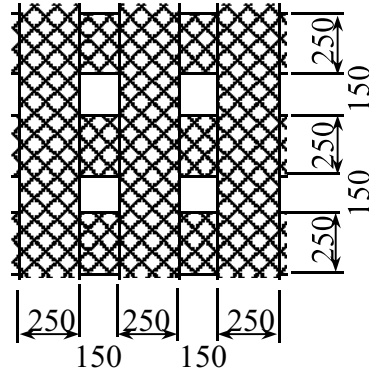
**2. Application Criteria**

The related strengthening system for the concrete deck slab shall generally consists of woven carbon fiber sheet (CFS) reinforcing layers, bonded to the concrete surface with epoxy adhesive.

The continuous arrangement is commonly used during the early stage of CFS bonding application at the bottom of the deck slab. However, in most of the cases observed, entrapped air which could not be easily released, was found in the installed CFS. These air voids reduce bond strength between CFS and concrete surface and must be squeezed by roller. Meanwhile, in the grid arrangement, CFS does not totally cover the required surface. Instead, the CFS is installed in strap-type method in both directions. According to experimental results, effectiveness of the second system is almost the same as that of the continuous arrangement. Moreover, entrapped air in the second system can be squeezed out easily using a roller. Thus, in this manual, the grid arrangement is recommended considering its ease of application, least cost and acceptable effectiveness. The carbon fiber sheet should be applied as two layers in both the longitudinal and transversal directions, as shown in Figure 3-8-2.

MAJOR REPAIR METHODS		
Defect/Deficiency	Crack on Deck Slab, Efflorescence	PLATE 3-8
Remedial Measure	Carbon Fiber Sheet Bonding	

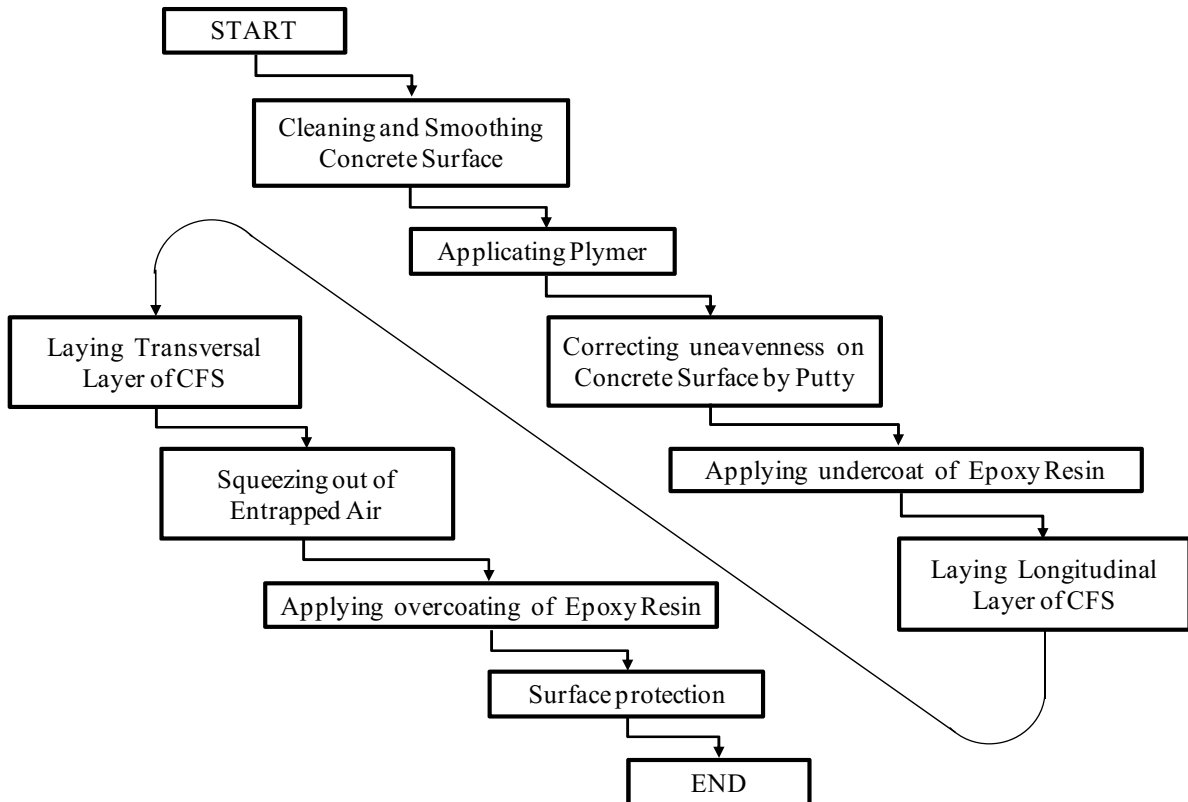
Figure 3-8-2 Carbon Fiber Sheet Arrangement



### 3. Work sequence

Work sequence of Patching Carbon Fiber Sheet Bonding is as shown in Figure 3-8-3.

Figure 3-8-3 Work sequence of Carbon Fiber Sheet Bonding



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Deck Slab, Efflorescence</b>	<b>PLATE 3-8</b>
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<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>
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### 4. Required Equipment/Tool and Material

1) Equipment/Tools

The following Equipment/Tools will be necessary for Carbon Fiber Sheet Bonding works:

- Abrasive Sandblaster
- Air Compressor
- Disc Grinder
- Portable Generator
- Paint Roller/Brush

2) Material

The following Materials will be necessary for Carbon Fiber Sheet Bonding works:

Carbon Fiber Products

- CFS (Strap Type)

Epoxy Materials

- Epoxy primer
- Epoxy putty
- Epoxy resin adhesive

### 5. Requirement, Specifications

5-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier.

1) Carbon Fiber Sheet (CFS)

The CFS shall conform to the requirements of the specifications shown in Table 3-8-1, (or Table 3-9-1) or equivalent ASTM Specifications.

**Table 3-8-1 Specification of CFS**

Property	Specifications	Test method
Fiber Areal Weight	300 g/m <sup>2</sup> above	ISO 18319
Design thickness	0.167 mm	ISO 18319
Tensile strength	3400 N/mm <sup>2</sup> above	ISO 10406-2
Tensile bond to concrete	1.5 N/mm <sup>2</sup> above	ISO 10406-2
Young's modulus	(2.45 ± 0.24) x10 <sup>5</sup> N/mm <sup>2</sup>	ISO 10406-2

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Deck Slab, Efflorescence</b>	<b>PLATE 3-8</b>
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<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>
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### 2) Epoxy Resin Adhesive

The Epoxy Resin Adhesive shall conform to the requirements of the specifications shown in Table 3-8-2, or equivalent ISO Specifications.

**Table 3-8-2 Specification of Epoxy Resin Adhesive**

Property	Test Method	Unit	Primer	Epoxy Putty	Penetrating Epoxy Resin
Viscosity	ASTM D2393	mPa.s	1000 below	Paste-like	20,000 ± 5000
Modulus of Elasticity	ASTM D695M	N/mm <sup>2</sup>	1500/above	1500/above	1500/above
Slant Shear Bond to Concrete	ASTM C882	N/mm <sup>2</sup>	15	15	15
Bond Strength to Concrete Dry/ Wet	ASTM D7234	N/mm <sup>2</sup>	1.5 above	1.5 above	1.5 above

### 5-2 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.

#### 1) Surface preparation

Disc grinder or abrasive sandblasting is used to clean and smoothen the concrete surface.

All concrete surfaces shall be clean, sound and free from surface moisture. Crack sealing or water proofing shall be provided prior to concrete surface restoration.



If water leaks through cracks on concrete surface to be covered with CFS, surface preparation and application of the CFS shall be in accordance with the approved manufacturer's specifications.

Both the Contractor and the manufacturer's technical representative must verify suitability of any changes to the application methods proposed by the Engineer. Cracks larger than 0.3 mm shall be injected with epoxy using a system/method approved by the Engineer

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Deck Slab, Efflorescence</b>	<b>PLATE 3-8</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>	

### 2) Application of Primer

The surface is coated with a primer resin to increase the strength of concrete surface and improve its bonding with CFS.

Contact surface shall be dry before coating with primer.

The primer should be formulated and compatible to the carbon fiber material and should not be applied when raining, during stormy weather, when air is misty or when conditions remain unsatisfactory in the opinion of the Engineer.

Application rate shall be such as to ensure complete saturation of the contact surface. Primer should be cured between 2~3 hours before proceeding to the next step.

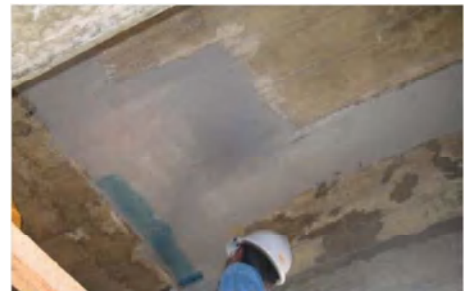


### 3) Adjustment of Unevenness with Putty

Any concave, pores, gaps on the concrete surface must be smoothed using epoxy putty. This work involves application of epoxy putty onto the primer-coated concrete surface, using trowel or spatula, to smoothen the surface. The putty is applied when the primer is already tack-free.

The application method is as follows:

- ✓ Mix 2 parts of epoxy putty until the mixture is homogenized.
- ✓ Apply the putty to smoothen the surface. Allowable unevenness after putty application is 1 mm/m




### 4) Application of Epoxy Resin for Undercoat

When the epoxy putty becomes tack-free, epoxy resin is applied to the concrete, acting as adhesive to bond the CFS. The molded composite is achieved as the resin impregnates into the CFS.

Prior to undercoating epoxy resin adhesive, ambient temperature at the work site shall be checked to confirm the curing conditions for applying the resin.

The Contractor shall check and confirm that the primer and putty have become tack-free and that no clay and dust exist on the concrete surface prior to Engineer's inspection. If there is a time interval of longer than 3 days after the primer and putty application, the



<b>MAJOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Crack on Deck Slab, Efflorescence</b>	<b>PLATE 3-8</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>	
<p>coated surface should be roughened with sandpaper and cleaned before the resin application</p> <p>The contact surface condition shall be tack-free and application shall not be done when raining,, air is misty, or when in the opinion of the Engineer, conditions are unsatisfactory to carry on with the work. The following specified quantity of the resin is estimated for reference only. The actual quantity should be determined in consideration with ambient temperature and manufacturer’s recommendations, subject to Engineer’s approval.</p> <ul style="list-style-type: none"> <li>✓ Mix the 2 parts of epoxy resin until homogenized,</li> <li>✓ Apply the epoxy resin on the surface at a rate of 0.5 kg/sq.m,</li> </ul> <p>5) Putting Longitudinal Layer of CFS</p> <p>Properly aligned CFS strips are installed in longitudinal direction to the adhesive coated concrete surface.</p> <p>Press the carbon fiber sheet by using plastic roller starting from the center toward the edge.</p> <p>The ideal length of carbon sheet is the full length of the slab. It should be avoid wrinkles with adequate caution.</p> <p>The CFS shall be applied as per the following:</p> <ul style="list-style-type: none"> <li>✓ Stick the CFS in the longitudinal direction with a reasonable lapse of 20~30 minutes after the epoxy resin application,</li> <li>✓ Press the CFS using a roller (plastic roller is preferred) starting from the center towards the edge to squeeze out entrapped air before the epoxy resin sets.</li> <li>✓ When lapping of two CFS is required, a lap length of not less than 20 cm shall be provided.</li> </ul> <p>The specified normal curing time is only for reference purposes. The actual curing period should be determined in consideration of the ambient temperature and manufacturer’s recommendation for the work site, subject to Engineer’s approval.</p>		
		

## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Crack on Deck Slab, Efflorescence**

**PLATE 3-8**

**Remedial Measure**

**Carbon Fiber Sheet Bonding**

6) Putting Transverse Layer of CFS

Properly aligned CFS strips are installed in the transverse direction to the adhesive coated concrete surface. Press the carbon fiber sheet by using plastic roller starting from the center toward the edge.

After the longitudinal layer CFS application, the transverse layer CFS is applied at right angles to but in the same manner as the longitudinal application.



7) Squeezing of Strip to Entrapped Air

For complete impregnation, entrapped air is squeezed out of the strips using the roller, before the adhesive sets. Do not apply the roller against the direction of the placed CFS to avoid damaging the material



8) Over-Coat Application using Epoxy Resin

Mixing and application procedure for the overcoat shall be similar to that of the under-coating resin. The standard quantity of over-coating resin is 0.2 kg/m<sup>2</sup>.

The actual quantity should be determined in consideration of the ambient temperature and manufacturer's recommendation for the work site, subject to Engineer's approval.

9) Surface Protection

For safety purposes, fireproof protection coating may be applied to the finished surface.

10) Quality Control and Inspection

The Contractor shall conduct a quality control program that includes, but is not limited to, the following:

- ✓ Inspection of all materials to ensure conformity with contract requirements, and that all materials are new and undamaged.
- ✓ Inspection of all surface preparation carried out prior to CFS application.
- ✓ Inspection of work in progress to ensure work is being done in accordance with approved manufacturer's instructions.



**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Crack on Deck Slab, Efflorescence</b>	<b>PLATE 3-8</b>
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<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>
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- ✓ Inspection of all work completed including verification of all repairs for debonding, and correction of any defective work.
  
- ✓ After allowing at least 24 hours for initial resin saturate to cure, the Contractor shall perform a visual and acoustic tap test inspection of the layered surface. All voids, bubbles and delaminations shall be repaired in accordance with manufacturer’s recommendations. The Contractor shall conduct adhesion testing of the fully cured CFS and assembly using direct pull-off tests, at locations determined by the Engineer. Failure at the bond line at tensile stress below 14kgf/cm<sup>2</sup> (200 psi) shall be cause for rejecting the repair works. A minimum of two pull-off tests per system (span) shall be performed. The test shall be completed prior to the application of the protective top coat on the CFS.

**6. Measurement and Payment**

6-1 Method of Measurement

CFS performed in accordance with the plans and specifications will be measured in square meters, while the carbon fiber plate in linear meters. The quantity to be considered for payment will include the CFS and carbon fiber plate used and accepted by the Engineer. No measurement will be made for epoxy injection of cracks, if required.

6-2 Basis of Payment

The quantity, measured as prescribed above, shall be paid for at a contract unit price. Epoxy injection of cracks will not be paid for directly and is considered subsidiary to the works. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related services necessary for strengthening the concrete, as detailed in the plans and specifications. If an alternate carbon fiber system is used, the price shall also include all engineering, design, and technical services, as well as contractor submittals required in the specifications.

Pay Item No.	Name	Unit of Measurement
3-8	Carbon Fiber Sheet Bonding (Deck slab)	Square Meter (m <sup>2</sup> )

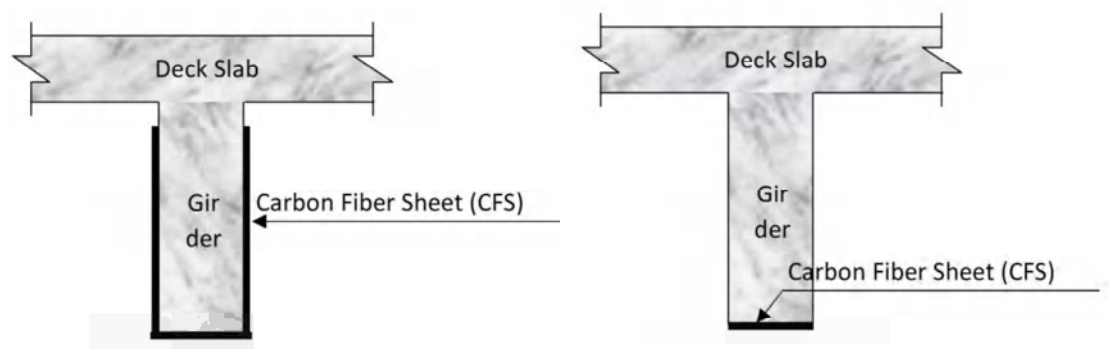
**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 9</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>	

**1. Work description**

Carbon Fiber Sheet for reinforced repair and strengthening systems are combination of carbon fiber sheet material and resins such as epoxies and other adhesive materials, acting as a composite material to enhance the capacity and extend the life of concrete structures as shown in Figure 3-9-1. The role of the resin is to serve as adhesive bond to the concrete surface and facilitate the transfer of stresses to and from the carbon fiber sheet.

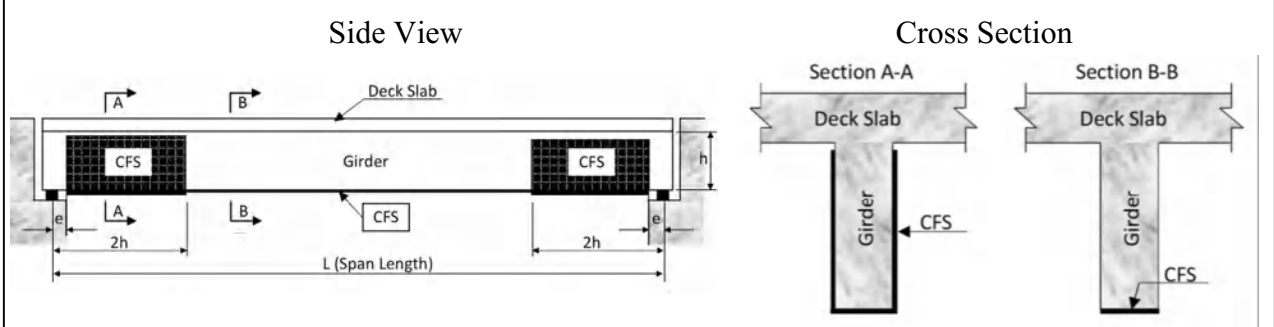
**Figure 3-9-1 Reinforcing Girder by Carbon Fiber Sheet**



**2. Application Criteria**

The Carbon Fiber Sheet (CFS) system for concrete girder generally consists of woven CFS reinforcing layers bonded to the concrete surface with epoxy. As shown in Figure 3-9-2, the section of  $2h$  in span from both ends (A-A) is applied with U-formed CFS as protection against shear cracks (Photo 9-1) while the full span length (B-B) is applied with first CFS layer for protection against flexural cracks (Photo 9-2) caused by live load. For practical reason, along both edge distances ( $e$ ) let free of CFS.

**Figure 3-9-2 Typical application method of CFS**



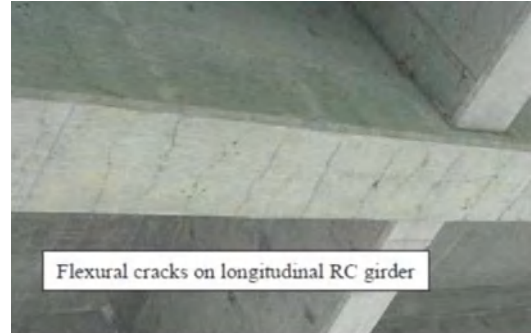
## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 9</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>	

**Photo 9-1 Example of Shear Crack**



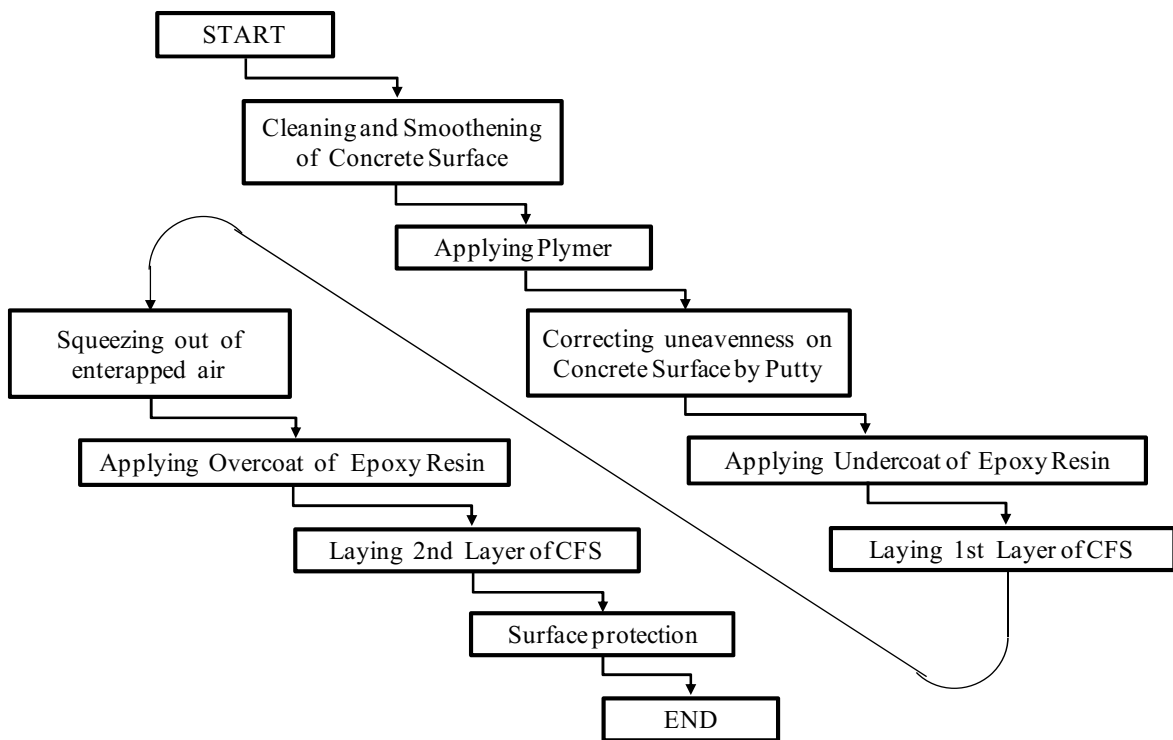
**Photo 9-2 Example of Flexural Crack**



### 3. Work sequence

Work sequence of Patching Carbon Fiber Sheet Bonding is as shown Figure 3-9-3.

**Figure 3-9-3 Work sequence of Carbon Fiber Sheet Bonding**



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 9</b>
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<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>
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### 4. Required Equipment/Tool and Material

1) Equipment/Tools

The following Equipment/Tools will be necessary for Carbon Fiber Sheet Bonding works:

- Abrasive Sandblaster
- Air Compressor
- Disc Grinder
- Portable Generator
- Paint Roller/Brush

2) Materials

The following Materials will be necessary for Carbon Fiber Sheet Bonding works:

Carbon Fiber Products

- CFS (longitudinal) for bending strengthening
- CFS (vertical) for shear strengthening

Epoxy Materials

- Epoxy primer
- Epoxy putty
- Epoxy resin adhesive

### 5. Requirement, Specifications

5-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier.

1) Carbon Fiber Sheet (CFS)

The CFS shall conform to the requirements of the specifications shown in Table 3-9-1, or Table 3-8-1.

**Table 3-9-1 Specification of CFS**

Property	Specifications	Test method
Fiber Areal Weight	300 g/m <sup>2</sup> above	ISO 18319
Design thickness	0.163 mm	ISO 18319
Tensile strength	2400 N/mm <sup>2</sup> above	ISO 10406-2
Tensile bond to concrete	1.5 N/mm <sup>2</sup> above	ISO 10406-2
Young's modulus	(4.40 ± 0.44) x 10 <sup>5</sup> N/mm <sup>2</sup>	ISO 10406-2

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 9</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>	

### 2) Epoxy Resin Adhesive

The Epoxy Resin Adhesive shall conform to the requirements of the specifications shown in Table 3-9-2, or equivalent ISO Specifications.

**Table 3-9-2 Specification of Epoxy Resin Adhesive**

Property	Test Method	Unit	Primer	Epoxy Putty	Penetrating Epoxy Resin
Viscosity	ASTM D2393	mPa.s	1000 below	Paste-like	20,000 ± 5000
Tensile Strength	ASTM D638M	N/mm <sup>2</sup>	15 above	-	30 above
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	20 above	15 above	40 above
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	20 above	40 above	50 above
Modulus of Elasticity	ASTM D695M	N/mm <sup>2</sup>	1500	1500	1500
Slant Shear Bond to Concrete	ASTM C882	N/mm <sup>2</sup>	15	15	15
Bond Strength	ASTM D7234	N/mm <sup>2</sup>	1.5 above	1.5 above	1.5 above
Dry		N/mm <sup>2</sup>	1.5 above	1.5 above	1.5 above
Wet		N/mm <sup>2</sup>	1.5 above	1.5 above	1.5 above

### 5-2 Work Requirement

The Contractor shall submit the Methodology Statement of the Work to the Engineer for his review and approval before commencement of the work.

#### 1) Surface preparation

Disc grinder or abrasive sandblasting is used to clean the concrete and to ensure that the surface roughness is even and smooth. To avoid pollution impact to soil and water, dust, cement, paint and other contaminants shall be contained by covering the bridge with plastic sheeting.



All concrete surfaces shall be clean, sound and free from surface moisture. Crack sealing or water proofing shall be provided prior to concrete surface restoration. If water leaks through cracks on concrete surface to be covered with CFS, surface preparation and application of the CFS shall be in accordance with the approved manufacturer's application specifications. Both the Contractor and the manufacturer's technical representative must verify the suitability of any changes to the application methods proposed by the Engineer. Cracks larger than 0.3 mm shall be injected with epoxy using a system/method approved by the Engineer

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 9</b>
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<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>
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2) Material handling

The carbon fiber components shall be delivered in original, unopened (except carbon fabric or strips) containers clearly marked with the manufacturer's name, product identification, and batch numbers. Storage and handling of the various products shall be in conformity with the manufacturer's recommendations and instructions.

3) Application of Primer

Primer resin soaks into the surface of concrete, resulting in increased strength of the concrete surface and improved bonding with CFS.

Contact surface shall be dry before coating with primer. The primer should be formulated and compatible with the carbon fiber material and not to be applied during rains, storms or when the air is misty or when conditions are unsatisfactory in the opinion of the Engineer.



Application rate shall be such as to ensure complete saturation of the contact surface. Primer should be cured between 2~3 hours before proceeding to the next step.

4) Adjustment of Unevenness with Putty

Any concave, pores, gaps on the concrete surface must be smoothed using epoxy putty. After the putty becomes tack-free, it is required to roughen the surface with sandpaper, then cleaned.

This work involves application of epoxy putty onto the primer coated concrete surface, using trowel or spatula, to smoothen the surface. The putty is applied when the primer is already tack-free.



The application method is as follows:

- ✓ Mix 2 parts of epoxy putty until the mixture is homogenized.
- ✓ Apply the putty to smoothen the surface. Allowable unevenness after putty application is 1 mm/m

5) Application of Epoxy Resin for Undercoat

Using roller, epoxy resin is applied to the concrete as adhesive to bond with the CFS. It forms a molded composite by impregnating into the CFS. Prior to undercoating epoxy resin adhesive, ambient temperature at the work site shall be checked to confirm the curing conditions of the applying the resin.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 9</b>
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<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>
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The contractor shall check and confirm that the primer and putty have become tack-free and there is no clay and dust on the concrete surface prior to Engineer's Inspection.

If there is a time interval of longer than 3 days after the primer and putty application, the primer and putty coated surface should be roughened with sandpaper, and the surface cleaned before the adhesive application



The contact surface condition shall be tack-free and application shall not be done during rains or storms or when the air is misty, or when in the opinion of the Engineer, conditions are unsatisfactory to carry out the work. The following specified quantity of the resin is only reference. The actual quantity should be determined in consideration of ambient temperature and manufacturer's recommendation for the work site, subject to Engineer's approval.

- ✓ The mixing and application of the adhesive (resin and hardener) should be in accordance with the manufacturer's instructions approved by the Engineer.
- ✓ Apply the epoxy resin on the surface at the rate of 0.7 kg/sq.m

6) Putting 1<sup>st</sup> Layer of CFS (longitudinal)

Properly aligned CFS is installed to the resin coated concrete surface to strengthen the section.

Press the CFS using deformed roller, starting from the center toward the edges.

The ideal length of carbon sheet is the full length of the girder. It should be avoid wrinkles with adequate caution. The CFS shall be applied in accordance with the following procedures:

- ✓ Stick the CFS in the longitudinal direction with a reasonable lapse of 20 to 30 minutes after the epoxy resin application,
- ✓ Press the CFS using a roller (plastic roller is preferred) starting from the center towards the edge to squeeze out entrapped air before the epoxy resin sets.
- ✓ When lapping of two CFS is required, a lap length of not less than 20 cm shall be provided.



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 9</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>	

The specified normal curing time is only for reference purposes. The actual curing period should be determined in consideration of the ambient temperature and manufacturer's recommendation for the work site, subject to Engineer's approval.

7) Squeezing out Entrapped Air

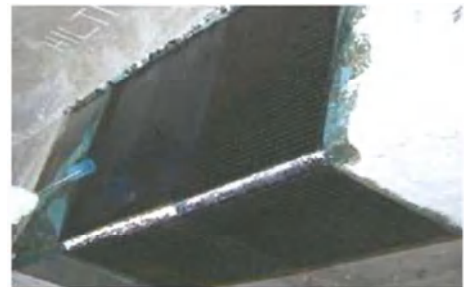
For complete impregnation, entrapped air is squeezed out of the strips using the roller, before the adhesive sets. Do not apply the roller against the direction of the placed CFS to avoid damaging the material.



8) Overcoat Application using Epoxy Resin

Epoxy resin is roller-applied to the 1<sup>st</sup> layer of CFS as adhesive to bond to 2<sup>nd</sup> layer, and to form a molded composite by impregnating into the CFS.

Verification and confirmation of resin mixing and application procedure shall be executed similar to that of the under-coating resin. The standard quantity of over-coating resin of 0.2 - 0.3 kg/m<sup>2</sup> shall be for reference purposes only.



The actual quantity should be determined in consideration of ambient temperature and manufacturer's recommendation for the work site, subject to Engineer's approval.

9) Putting 2<sup>nd</sup> Layer of CFS

Properly aligned CFS strips (2<sup>nd</sup> layer) are laid onto to the resin overcoated surface to further strengthen the section.

Press the CFS using deformed roller starting from the center toward the edges.

Repeat the steps for the 1<sup>st</sup> layer CFS laying works but for a vertical (transverse) direction.

Surface Protection

For safety purposes, fireproof protection coating may be applied to the finished surface.



10) Quality Control and Inspection

The Contractor shall conduct a quality control program that includes, but not limited to, the following:



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 9</b>
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<b>Remedial Measure</b>	<b>Carbon Fiber Sheet Bonding</b>
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- ✓ Inspection of all materials to ensure conformity with contract requirements, and that all materials are new and undamaged.
- ✓ Inspection of all surface preparation carried out prior to CFS application.
- ✓ Inspection of work in progress to ensure work is being done in accordance with approved manufacturer's instructions.
- ✓ Inspection of all work completed including verification of all repairs for debonding and correction of any defective work.

11) Testing

After allowing at least 24 hours for initial resin saturate to cure, the Contractor shall perform a visual and acoustic tap test inspection of the layered surface. All voids, bubbles and delaminations shall be repaired in accordance with manufacturer's recommendations. The Contractor shall conduct adhesion testing of the fully cured CFS and assembly using direct pull-off tests, at locations determined by the Engineer. Failure at the bond line at tensile stress below 14kgf/cm<sup>2</sup> (200 psi) shall be cause for rejecting the repair works. A minimum of two pull-off tests per system (span) shall be performed. The test shall be completed prior to the application of the protective top coat on the CFS.

### 6. Measurement and Payment

6-1 Method of Measurement

CFS performed in accordance with the plans and specifications will be measured in square meters. The quantity to be considered for payment will include the CFS used and accepted by the Engineer. No measurement will be made for epoxy injection of cracks, if required.

6-2 Basis of Payment

The quantity, measured as prescribed above, shall be paid for at a contract unit price. Epoxy injection of cracks will not be paid for directly and is considered subsidiary to the works. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related services necessary for strengthening the concrete, as detailed in the plans and specifications. If an alternate carbon fiber system is used, the price shall also include all engineering, design, and technical services, as well as contractor submittals required in the specifications.

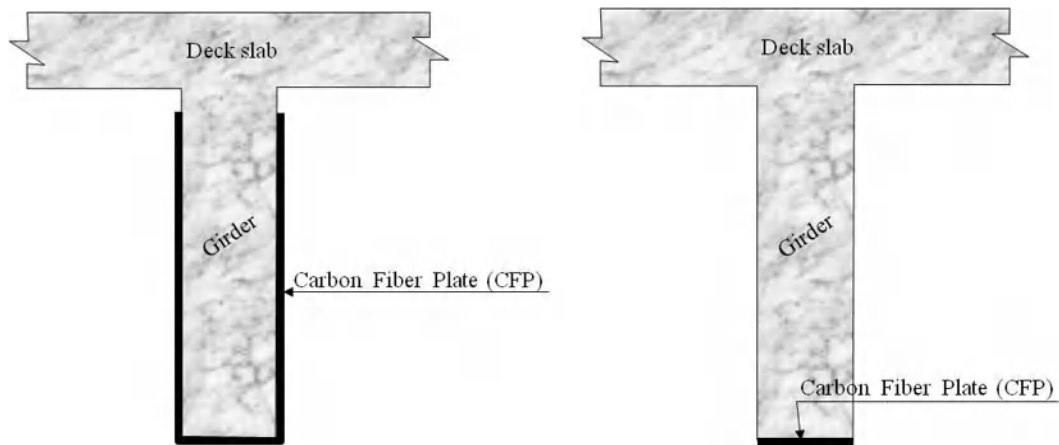
Pay Item No.	Name	Unit of Measurement
3-9	Carbon Fiber Sheet Bonding to Concrete Girder	Square Meter (m <sup>2</sup> )

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 10</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Plate Bonding</b>	

Carbon Fiber Plate for reinforced repair and strengthening system is a combination of Carbon Fiber Plate material and resins such as epoxies and other adhesive materials, acting as a composite material to enhance the capacity and extend the life of concrete structures as shown in Figure 3-10-1. The role of the resin is to serve as adhesive bond to the concrete surface and facilitate the transfer of stresses to and from the carbon fiber plate.

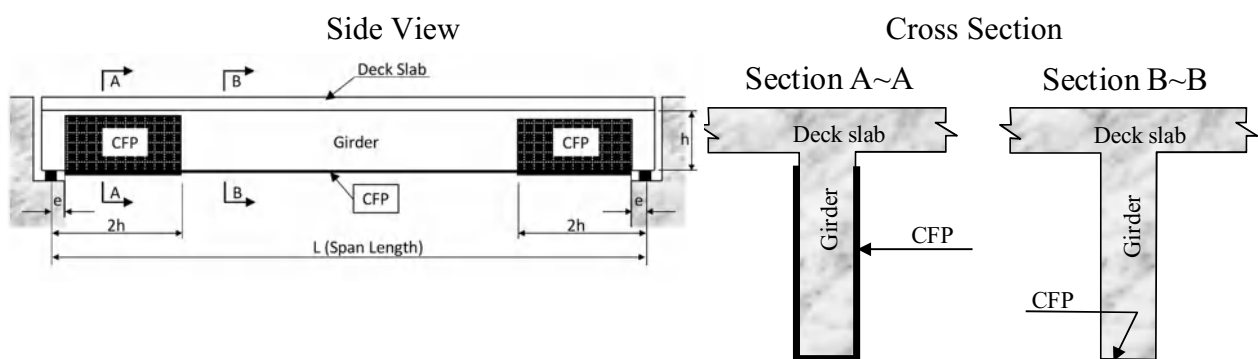
**Figure 3-10-1 Reinforcing Girder by Carbon Fiber Plate**



The Carbon Fiber Plate (CFP) system for concrete girder generally consists of Carbon Fiber Plate bonded to the concrete surface with epoxy.

As shown in Figure 3-10-2, the section of  $2h$  in span from both ends (A-A) is applied with U-formed CFP as protection against shear cracks (Photo 10-1) while the full span length (B-B) is applied with first CFP layer for protection against flexural cracks (Photo 10-2) caused by live load. For practical reason, along both edge distances ( $e$ ) let free of CFP.

**Figure 3-10-2 Typical application method of CFP**



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 10</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Plate Bonding</b>	

**Photo 10-1 Example of Shear Crack**



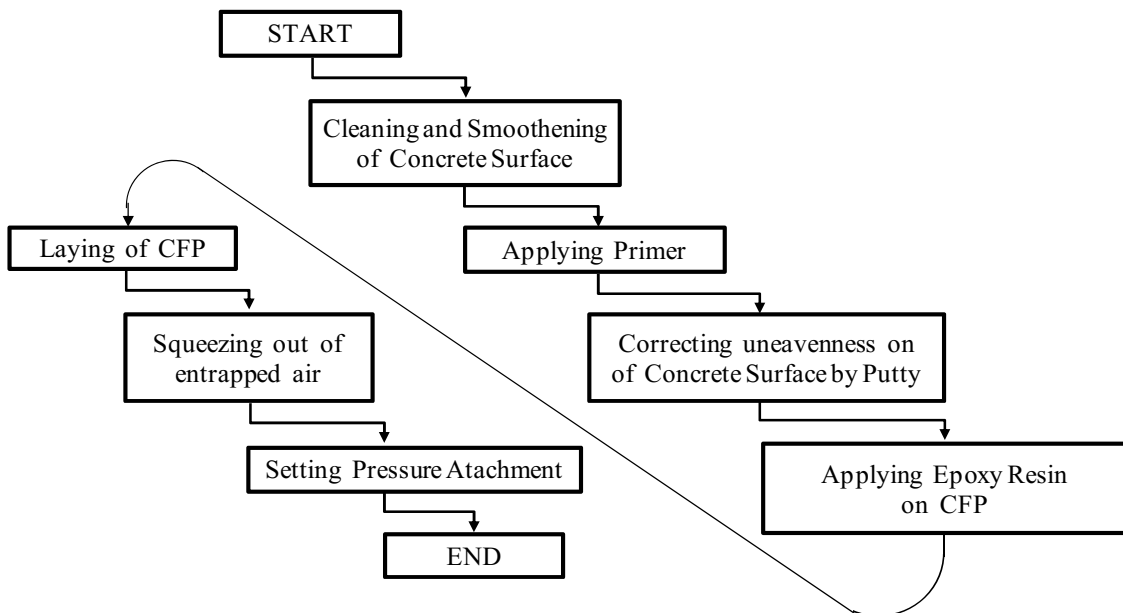
**Photo 10-2 Example of Flexural Crack**



### 2. Work sequence

Work sequence of Carbon Fiber Plate Bonding is as shown in Figure 3-10-3.

**Figure 3-10-3 Work sequence of Carbon Fiber Plate Bonding**



### 3. Required Equipment/Tool and Material

1) Equipment/Tool

Following Equipment/Tool will be necessary for Carbon Fiber Plate Bonding works:

-Abrasive Sandblaster

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 10</b>
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<b>Remedial Measure</b>	<b>Carbon Fiber Plate Bonding</b>
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- Air Compressor
- Disc Grinder
- Portable Generator
- Paint Roller/Brush

### 2) Material

The following Material will be necessary for Carbon Fiber Plate Bonding works:

#### Carbon Fiber Products

- CFP (longitudinal)
- CFP (vertical)

#### Epoxy Materials

- Epoxy primer
- Epoxy putty
- Epoxy resin adhesive

## 5. Requirement, Specifications

### 5-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier.

#### 1) Carbon Fiber Plate (CFP)

CFP shall conform to the requirements of the specifications shown in Table 3-10-1, or equivalent ISO Specifications.

The Thickness and Young modulus are given in form of CFP.

**Table 3-10-1 Specification of CFP**

Property	Test Method	Unit	Specifications
CFP Tensile Strength	ASTM D3039	N/mm <sup>2</sup>	2400
Bond Strength to Concrete	ASTM D7234	N/mm <sup>2</sup>	1.5 above
Dry			
Wet			1.5 above

#### 2) Epoxy Resin Adhesive

The Epoxy Resin Adhesive shall conform to the requirements of the specifications shown in Table 3-10-2, or equivalent ISO Specifications.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 10</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Plate Bonding</b>	

**Table 3-10-2 Specification of Epoxy Resin Adhesive**

Property	Test Method	Unit	Specification
Specific Gravity	ASTM D792	-	3-4±0.20
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	45
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	70
Modulus of Elasticity	ASTM D695M	N/mm <sup>2</sup>	4000
Tensile Strength	ASTM D638M	N/mm <sup>2</sup>	25
Tensile Shear Bond	ASTM D1002	N/mm <sup>2</sup>	15
Bond Strength to CFP & Steel	ASTM D7234	N/mm <sup>2</sup>	3.5

### 5-2 Work Requirement

The Contractor shall submit the Methodology Statement of the Work to the Engineer for his review and approval before commencement of the work.

#### 1) Surface preparation

Disc grinder or abrasive sandblasting is used to clean the concrete and to ensure that the surface roughness is even and smooth. To avoid pollution impact to soil and water, dust, cement, paint and other contaminants were contained by covering the bridge with plastic sheeting.



All concrete surfaces shall be clean, sound and free from surface moisture. Crack sealing or water proofing shall be provided prior to concrete surface restoration. If water leaks through cracks on concrete surface to be covered with CFS, surface preparation and application of the CFP shall be in accordance with the approved manufacturer's application specifications. Both the Contractor and the manufacturer's technical representative must verify the suitability of any changes to the application methods proposed by the Engineer. Cracks larger than 0.3 mm shall be injected with epoxy using a system/method approved by the Engineer

#### 2) Material handling

The carbon fiber components shall be delivered in original, unopened (except carbon fabric or strips) containers clearly marked with the manufacturer's name, product identification, and batch numbers. Storage and handling of the various products shall be

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 10</b>
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<b>Remedial Measure</b>	<b>Carbon Fiber Plate Bonding</b>
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in conformity with the manufacturer's recommendations and instructions.

### 3) Application of Primer

Primer resin soaks into the surface of concrete, resulting in increased strength of the concrete surface and improved bonding with CFP.

Contact surface shall be dry before coating with primer. The primer should be formulated and compatible with the carbon fiber material and shall not be applied during rains, storms or when the air is misty or when conditions are unsatisfactory in the opinion of the Engineer.



Application rate shall be such as to ensure complete saturation of the contact surface.

Primer should be cured between 2~3 hours before proceeding to the next step.

### 4) Adjustment of Unevenness with Putty

Any concave, pores, gaps on the concrete surface must be smoothed using epoxy putty. After the putty becomes tack-free, the surface is roughened with sandpaper and then cleaned.

This work involves application of epoxy putty onto the primer coated concrete surface, using trowel or spatula, to smoothen the surface. The putty is applied when the primer is already tack-free.



The application method is as follows:

- ✓ Mix 2 parts of epoxy putty until the mixture is homogenized.
- ✓ Apply the putty to smoothen the surface. Allowable unevenness after putty application is 1 mm/m
- ✓ Square Meter

### 5) Application of Epoxy Resin on CFP

In order to reduce the formation of voids, epoxy based adhesive is applied to the CFP with molder to bond, forming a curved profile measuring approximately 3 mm in the centre and 1 mm on the edges.

The Contractor shall submit for the Engineer's



**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 10</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Plate Bonding</b>	

approval, his proposed method of application of epoxy resin undercoat, in accordance with approved manufacturer’s specifications for the CFP system.

The contact surface condition shall be tack-free and application shall not be done during rain or storms or when the air is misty, or when in the opinion of the Engineer, conditions are unsatisfactorily to carry on with the work. The following specified quantity of the adhesive is only for reference. Actual quantity should be determined in consideration of ambient temperature and manufacturer’s recommendation for the work site, subject to Engineer’s approval.

- ✓ The mixing and application of the adhesive (resin and hardener) should be in accordance with the manufacturer’s instructions approved by the Engineer
- ✓ Apply the adhesive on the surface at the rate of 0.2 ~ 0.3 kg/m<sup>2</sup>

6) Putting CFP

Properly aligned CFP is installed longitudinally to the adhesive coated concrete surface.

Press the carbon fiber plate manually using deformed roller, starting from the center toward the edges.



CFP shall be applied full length of the girder and considering the following measures.

- ✓ CFP may be used at surfaces where some abrasion is required as per manufacturer’s recommendations, provided that the plates are manufactured according to the required roughness.
- ✓ Apply the adhesive on the surface at the rate of 0.4 ~ 0.5 kg/m<sup>2</sup>
- ✓ The adhesive layer shall be applied to the plates in a curved profile measuring 3 mm in the centre and 1 mm on the edges, in order to reduce formation of voids.
- ✓ During installation of CFP uniform pressure using roller should be applied, moving from the longitudinal centerline then outwards.

This is intended to expel excess adhesive and produce even edges.



7) Squeezing of Strip to Entrapped Air

For complete impregnation, entrapped air is

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 10</b>
<b>Remedial Measure</b>	<b>Carbon Fiber Plate Bonding</b>	

squeezed out the strips using the roller, before the adhesive sets. Surface Protection

8) Setting Pressure Attachment

Set at position of the girder, then press using wooden anchor frame and set bolts for curing.



9) Quality Control and Inspection

The Contractor shall conduct a quality control program that includes, but is not limited to, the following:

- ✓ Inspection of all materials to ensure conformity with contract requirements, and that all materials are new and undamaged.
- ✓ Inspection of all surface preparation carried out prior to CFP application.
- ✓ Inspection of work in progress to ensure work is being done in accordance with approved manufacturer's instructions.
- ✓ Inspection of all work completed including verification of all repairs for debonding, and correction of any defective work.

10) Testing

After allowing at least 24 hours for initial resin saturate to cure, the Contractor shall perform a visual and acoustic tap test inspection of the layered surface. All voids, bubbles and delaminations shall be repaired in accordance with manufacturer's recommendations. The Contractor shall conduct adhesion testing of the fully cured CFP and assembly using direct pull-off tests, at locations determined by the Engineer. Failure at the bond line at tensile stress below 14kgf/cm<sup>2</sup> (200 psi) shall be cause for rejecting the repair works. A minimum of two pull-off tests per system (span) shall be performed. The test shall be completed prior to the application of the protective top coat on the CFP.

### 6. Measurement and Payment

6-1 Method of Measurement

CFP performed in accordance with the plans and specifications will be measured in linear meters. The quantity to be considered for payment will include the CFP used and accepted by the Engineer. No measurement will be made for epoxy injection of cracks, if required.

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Crack on Concrete (Girder)</b>	<b>PLATE 3 - 10</b>
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<b>Remedial Measure</b>	<b>Carbon Fiber Plate Bonding</b>
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6-2 Basis of Payment

The quantity, measured as prescribed above, shall be paid for at a contract unit price. Epoxy injection of cracks will not be paid for directly and is considered subsidiary to the works. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related services necessary for strengthening the concrete, as detailed in the plans and specifications. If an alternate carbon fiber system is used, the price shall also include all engineering, design, and technical services, as well as contractor submittals required in the specifications.

Pay Item No.	Name	Unit of Measurement
3-10	Carbon Fiber Plate Bonding to Concrete Girder	Linear Meter (m)

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Crack in Steel Girder</b>	<b>PLATE 3 - 11</b>
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<b>Remedial Measure</b>	<b>Supplementing Steel Plate</b>
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**1. Work description**

Defects of a steel structure will be categorized as (i) Rusting/Corrosion, (ii) Crack/Breakage, (iii) Deformation, (iv) Losing/Missing bolts, etc.

Causes of above defects of the steel structure will be (i) Lack of maintenance of painting, (ii) Over stress due to heavy traffic, (iii) Vibration caused by traffic, (iv) Fatigue, (v) Lack of consideration of a detailed structural design, etc.

Supplemental steel plate is carried out to restore lost strength of the steel member by adding a new steel plate to a damaged area or by replacing damaged member with a new steel plate.

**2. Application criteria**

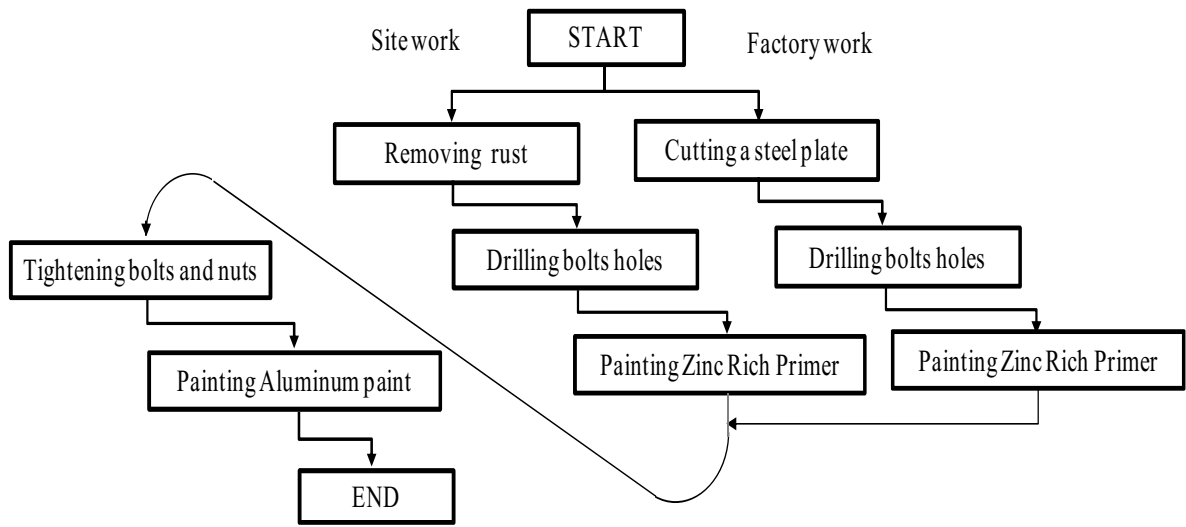
Supplemental steel plate without replacement of a member will be applicable to Crack/breakage of the member.

Supplemental steel plate with partial replacement of a member will be applicable to Deformation of the member.

**3. Work sequence**

Work sequence of Supplementing Steel Plate for steel girder end is as shown in Figure 3-11-1.

**Figure 3-11-1 Work sequence**



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack of Steel Pier</b>	<b>PLATE 3 - 11</b>
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<b>Remedial Measure</b>	<b>Supplementing Steel Plate</b>
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### 4. Required Equipment/Tool and Material

#### 4-1 Equipment/Tool

Following equipment/tool will be required for repair of the steel pier crack by Supplementing steel plate.

- Electric drill
- Fastening wrench
- Disk sander
- Wire brush
- Paint brush

#### 4-2 Material

Following equipment/tool will be required for repair of the steel pier crack by Supplementing steel plate

- Steel plate
- High tension bolt (HTB)
- Zinc rich primer
- Aluminum paint

### 5. Requirement, Specification

#### 5-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier.

##### 1) Steel material

- Steel plate: ASTM A36 or equivalent
- HTB: ASTM A325 or equivalent

##### 2) Zinc rich primer

Zinc rich primer shall conform to the requirements of the specifications shown in Table 3-12-1 or equivalent ASTM Specifications.

**Table 3-12-1 Specifications of Zinc rich primer**

Property	Test Method	Unit	Specifications
Gloss @ 60° Angle	ASTM D 523	—	Flat
Adhesion	ASTM D 3359	—	Minimum 3A
Salt Spray Resistance	ASTM D 117	—	Excellent
% Zinc by Weight in Dried Film Test	—	%	87.5 ± 2

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack of Steel Pier</b>	<b>PLATE 3 - 11</b>
<b>Remedial Measure</b>	<b>Supplementing Steel Plate</b>	

### 3) Aluminum paint

Aluminum paint shall conform to the requirements of the specifications shown in Table 3-11-2 or equivalent ASTM Specifications.

**Table 3-11-2 Specification of Aluminum paint**

Property	Test Method	Unit	Specifications
Adhesive test	ASTM D7234	—	7days 1.0 N/mm <sup>2</sup> , 28days 1.5 N/mm <sup>2</sup>
Elongation	ASTM C190	—	7days 0.40 %, 28days 0.40 %
Saltwater test	ASTM D6943	—	No defection

### 5-2 Work requirement

The contractor shall submit shop drawings and Methodology Procedures including scaffolding plan of the pier during repair works to the Engineer for his approval before commencement of the repair works.

#### 1) Preparation in a factory

Supplemental steel plates will be prepared in the factory where the steel plates are cut based on measured size and then drilled necessary number of bolts holes. Zinc rich primer of 2 layers shall be applied on all surfaces of the steel plates.

Thickness of Zinc rich primer of each layer is 75 $\mu$ m and minimum time interval of works is 8 hours.

#### 2) Preparation on the site

Scaffoldings to support a superstructure during repair works of the girder shall be installed. The scaffolding must have enough strength and certain foundation with enough bearing capacity to support the superstructure including traffic load.

Removing rust on the member to be repair

Rust/corrosion shall be removed from the member using power tool such as disk sander.

#### 3) Drilling bolt holes

Bolt holes are drilled on the member based on drawings. For example, set 2 Rows HT-Bolts @100mm to the lower web.



Before



After Supplementing Plate

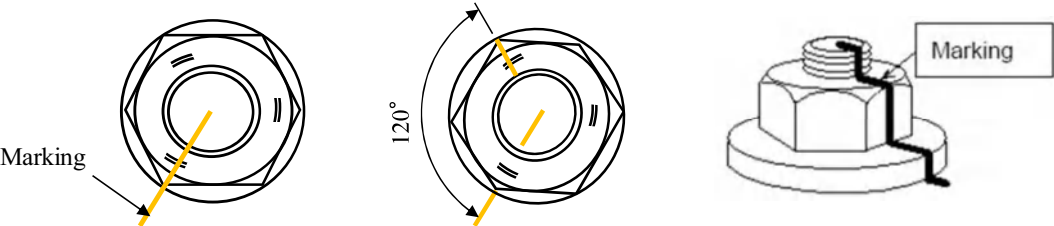
**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Crack of Steel Pier</b>	<b>PLATE 3 - 11</b>
<b>Remedial Measure</b>	<b>Supplementing Steel Plate</b>	

4) Painting Zinc rich primer  
 Zinc rich primer of 2 layers shall be applied on surfaces of the member. Thickness of Zinc rich primer of each layer is  $75\mu\text{m}$  and minimum time interval of works is 8 hours.

5) Applying the steel plate and tightening HTB  
 The supplementing steel plate shall be equivalent thickness to the web plate or flange plate. For example, for 12mm web plate, add 12mm plate and HTB M16, for 19mm flange plate, add 19mm plate and HTB M22 @ 100mm or 125mm distance.

Tightening of HTB will be carried out with 2 steps.  
 Step 1: Fastened using electric fastener. Marking shall be applied after tightening one by one by paint.  
 Step 2: HTB are finally tightened using Rotation Angle Method as a means of quality control to meet the required design tensile stress. The tightening rotation angle shall be  $120^{\circ}\pm 30^{\circ}$  from the location of the marking.



6) Painting top layer by Aluminum paint  
 Aluminum paint of 2 layers shall be applied on all surfaces of the steel plates. Thickness of Aluminum paint of each layer is  $50\mu\text{m}$  and minimum time interval of works is 4 hours.  
 The paint shall be applied widely around the supplement plates.

**6. Measurement and Payment**

6-1 Method of measurement  
 The method of measurement for supplementing steel plate shall be kilogram (kg) of the supplemented steel plate as shown the approved shop drawings. Weight of HTB sets is not included into the weight for measurement.

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Crack of Steel Pier</b>	<b>PLATE 3 - 11</b>
<b>Remedial Measure</b>	<b>Supplementing Steel Plate</b>	

6.2 Basis of Payment

The price and payment per kilogram (Kg) of Supplementing steel plate shall include full compensation for removal of rust/corrosion, painting, tightening HTBs all materials, labor, equipment, tools. It shall also include construction and removal of scaffoldings and other temporary works necessary to complete the Supplementing steel plate.

Pay Item No.	Name	Unit of Measurement
3-11	Supplementing Steel Plate	Kilogram (Kg)

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Crack of Steel Pier</b>	<b>PLATE 3 - 12</b>
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<b>Remedial Measure</b>	<b>Supplementing Steel Plate</b>
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**1. Work description**

Defects of a steel structure will be categorized as (i) Rusting/Corrosion, (ii) Crack/Breakage, (iii) Deformation, (iv) Losing/Missing bolts, etc.

Causes of above defects of the steel structure will be (i) Lack of maintenance of painting, (ii) Over stress due to heavy traffic, (iii) Vibration caused by traffic, (iv) Fatigue, (v) Lack of consideration of a detailed structural design, etc.

Supplemental steel plate is carried out to restore lost strength of the steel member by adding a new steel plate to a damaged area or by replacing damaged member with a new steel plate.

**2. Application criteria**

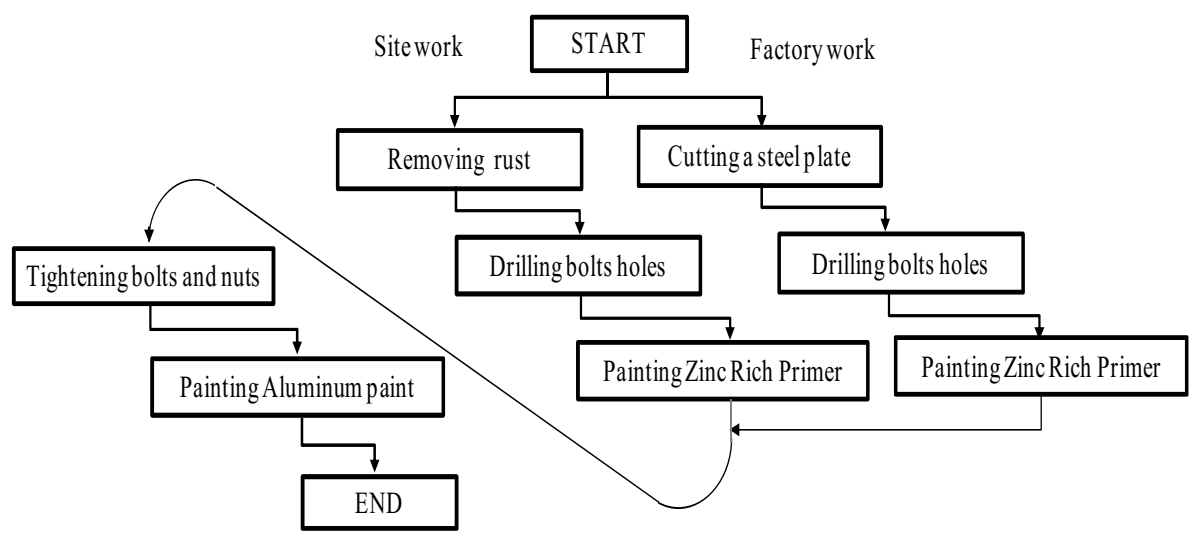
Supplemental steel plate without replacement of a member will be applicable to Crack/breakage of the member.

Supplemental steel plate with partial replacement of a member will be applicable to **Defamation** of the member.

**3. Work sequence**

Work sequence of Supplementing Steel Plate for steel pier is as shown in Figure 3-12-1.

**Figure 3-12-1 Work sequence**



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack of Steel Pier</b>	<b>PLATE 3 - 12</b>
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<b>Remedial Measure</b>	<b>Supplementing Steel Plate</b>
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### 4. Required Equipment/Tool and Material

#### 4-1 Equipment/Tool

Following equipment/tool will be required for repair of the steel pier crack by Supplementing steel plate.

- Electric drill
- Fastening wrench
- Disk sander
- Wire brush
- Paint brush

#### 4-2 Material

Following equipment/tool will be required for repair of the steel pier crack by Supplementing steel plate

- Steel plate
- High tension bolt (HTB)
- Zinc rich primer
- Aluminum paint

### 5. Requirement, Specification

#### 5-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier.

##### 1) Steel material

- Steel plate: ASTM A36 or equivalent
- HTB: ASTM A325 or equivalent

##### 2) Zinc rich primer

Zinc rich primer shall conform to the requirements of the specifications shown in Table 3-12-1 or equivalent ASTM Specifications.

**Table 3-12-1 Specifications of Zinc rich primer**

Property	Test Method	Unit	Specifications
Gloss @ 60° Angle	ASTM D 523	—	Flat
Adhesion	ASTM D 3359	—	Minimum 3A
Salt Spray Resistance	ASTM D 117	—	Excellent
% Zinc by Weight in Dried Film Test	—	%	87.5 ± 2

##### 3) Aluminum paint

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack of Steel Pier</b>	<b>PLATE 3 - 12</b>
<b>Remedial Measure</b>	<b>Supplementing Steel Plate</b>	

Aluminum paint shall conform to the requirements of the specifications shown in Table 3-12-2 or equivalent ASTM Specifications.

**Table 3-12-2 Specification of Aluminum paint**

Property	Test Method	Unit	Specifications
Adhesive test	ASTM D7234	—	7days 1.0 N/mm <sup>2</sup> , 28days 1.5 N/mm <sup>2</sup>
Elongation	ASTM C190	—	7days 0.40 %, 28days 0.40 %
Saltwater test	ASTM D6943	—	No deflection

### 5-2 Work requirement

The contractor shall submit shop drawings and Methodology Procedures including scaffolding plan of the pier during repair works to the Engineer for his approval before commencement of the repair works.

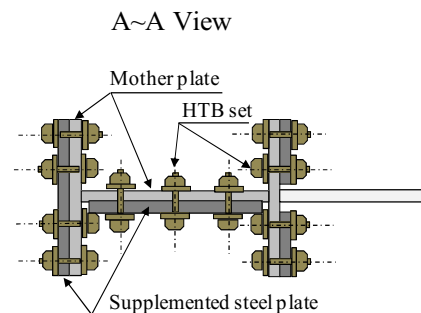
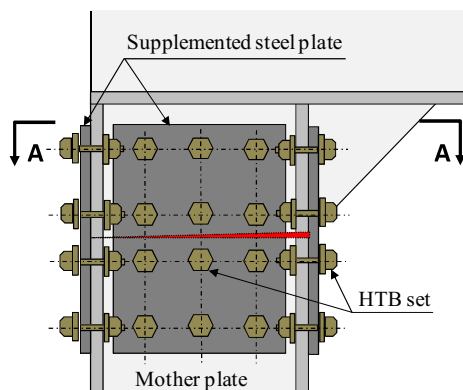
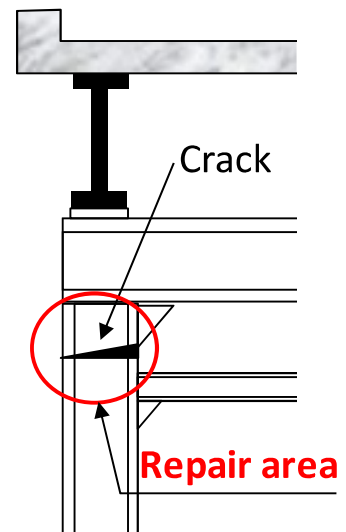
#### 1) Preparation in a factory

Supplemental steel plates will be prepared in the factory where the steel plates are cut based on measured size and then drilled necessary number of bolts holes. Zinc rich primer of 2 layers shall be applied on all surfaces of the steel plates.

Thickness of Zinc rich primer of each layer is 75 $\mu$ m and minimum time interval of works is 8 hours.

#### 2) Preparation on the site

Scaffoldings to support a superstructure during repair works of the pier shall be installed. The scaffolding must have enough strength and certain foundation with enough bearing capacity to support the superstructure including traffic load.



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Crack of Steel Pier</b>	<b>PLATE 3 - 12</b>
<b>Remedial Measure</b>	<b>Supplementing Steel Plate</b>	

Removing rust on the member to be repair

Rust/corrosion shall be removed from the member using power tool such as disk sander.

3) Drilling bolt holes

Bolt holes are drilled on the member based on drawings.

4) Painting Zinc rich primer

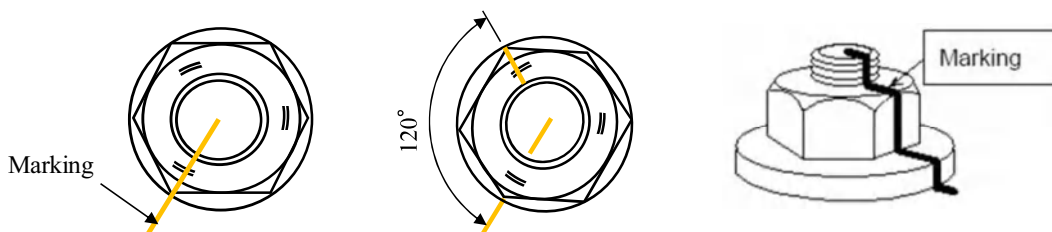
Zinc rich primer of 2 layers shall be applied on surfaces of the member. Thickness of Zinc rich primer of each layer is  $75\mu\text{m}$  and minimum time interval of works is 8 hours.

5) Applying the steel plate and tightening HTB

Tightening of HTB will be carried out with 2 steps.

Step 1: Fastened using electric fastener. Marking shall be applied after tightening one by one by paint.

Step 2: HTB are finally tightened using Rotation Angle Method as a means of quality control to meet the required design tensile stress. The tightening rotation angle shall be  $120^{\circ}\pm 30^{\circ}$  from the location of the marking.



6) Painting top layer by Aluminum paint

Aluminum paint of 2 layers shall be applied on all surfaces of the steel plates.

Thickness of Aluminum paint of each layer is  $50\mu\text{m}$  and minimum time interval of works is 4 hours.

### 6. Measurement and Payment

6-1 Method of measurement

The method of measurement for supplementing steel plate shall be kilogram (kg) of the supplemented steel plate as shown the approved shop drawings. Weight of HTB sets is not included into the weight for measurement.

6.2 Basis of Payment

The price and payment per kilogram (Kg) of Supplementing steel plate shall include full compensation for removal of rust/corrosion, painting, tightening HTBs all materials, labor,

**MAJOR REPAIR METHODS**


<b>Defect/Deficiency</b>	<b>Crack of Steel Pier</b>	<b>PLATE 3 - 12</b>
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<b>Remedial Measure</b>	<b>Supplementing Steel Plate</b>
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equipment, tools. It shall also include construction and removal of scaffoldings and other temporary works necessary to complete the Supplementing steel plate.

Pay Item No.	Name	Unit of Measurement
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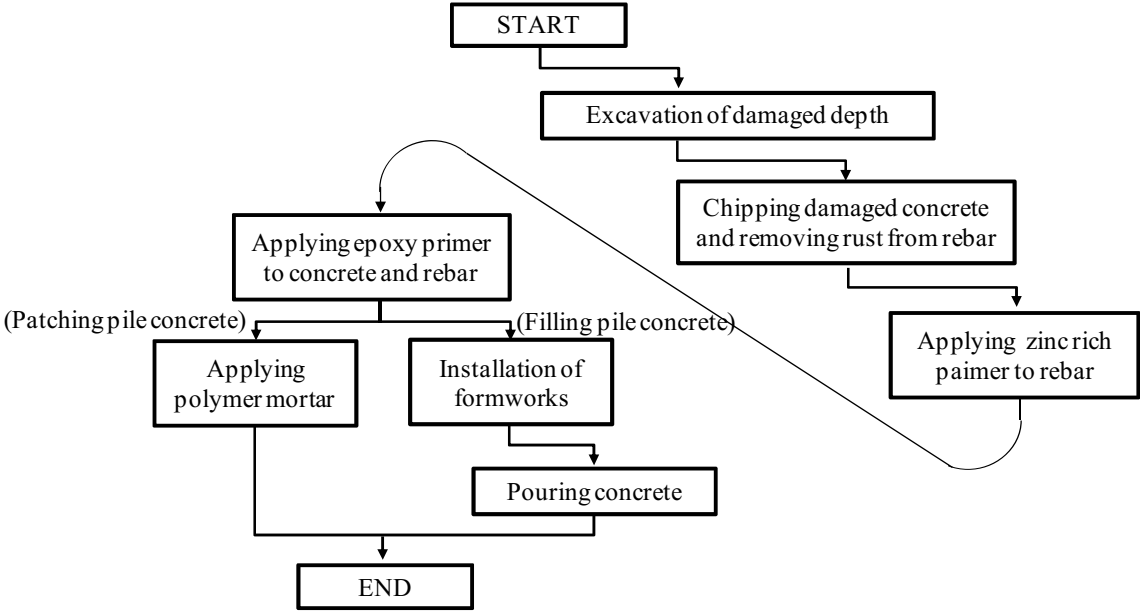
3-12	Supplementing Steel Plate	Kilogram (Kg)
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<b>MAJOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Spalling/Exposed Rebar of Bored Pile</b>	<b>PLATE 3 - 13</b>
<b>Remedial Measure</b>	<b>Filling pile mortar/concrete</b>	
<b>1. Work description</b>		
<p>Due to scouring some of bored pile head areas below a pile cap appear above ground surface with spalling cover concrete/missing concrete section and exposing rebar. Main cause of spalling can be supposed as lack of pile head treatment length, meanwhile, missing concrete section can be supposed as wrong measurement of the pile top elevation.</p> <p>Patching repair of bored concrete pile is performed to restore small areas where sound concrete is damaged by spalling, scaling and impact. This method of repair is generally applied using trowel and require none or minimum formworks.</p> <p>The other hand, Filling pile concrete is performed to restore missing concrete section of the bored pile where concrete of the section missed due to wrong measurement of the pile top elevation..</p> <p style="text-align: center;">Photo 13-1 Missing concrete and Exposed rebar</p> <div style="text-align: center;">  </div>		
<b>2. Application criteria</b>		
<p>Patching of pile concrete is applicable to the piles whose concrete spalling with rebar exposure. Patching of pile concrete applies to polymer cement mortar.</p> <p>Filling pile concrete is applicable to the pile which has missing section of concrete with rebar exposure. Filled concrete is Portland cement.</p>		
<b>3. Work sequence</b>		
<p>Work sequence of replacement method of Patching/Filling pile concrete is as shown in Figure 3-13-1.</p>		

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Spalling/Exposed Rebar of Bored Pile</b>	<b>PLATE 3 - 13</b>
<b>Remedial Measure</b>	<b>Filling pile mortar/concrete</b>	

**Figure 3-13-1 Work sequence**



**4. Required Equipment/Tool and Material**

**4-1 Equipment/Tool**

Following equipment/tool will be required for replacement works of the bearing shoe .

- Shovel
- Electrical Jackhammer
- Portable generator
- Chisel
- Trowel
- Painting brush

**4-2 Material**

Following equipment/tool will be required for replacement works of the bearing shoe.

- Portland Cement (Filling pile concrete)
- Polymer Cement (patching pile concrete)
- Epoxy Bonding Coat
- Zinc Rich Primer

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Spalling/Exposed Rebar of Bored Pile</b>	<b>PLATE 3 - 13</b>
<b>Remedial Measure</b>	<b>Filling pile mortar/concrete</b>	

### 5. Requirement, Specification

#### 5-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier.

#### 1) Polymer Cement

Polymer cement mortar shall conform to the requirements of the specifications shown in Table 3-13-1 or equivalent ASTM Specifications.

**Table 3-13-1 Specifications of Polymer Cement**

Property	Test Method	Unit	Specification
Thermal Expansion	ASTM C531	mm/mm°C	2.0 x 10 <sup>-5</sup>
Slant Shear Bond to Concrete	ASTM C882	N/mm <sup>2</sup>	1.5 /above
Compressive Strength (7days x 20°C)	ASTM C579	N/mm <sup>2</sup>	20 /above

#### 2) Corrosion Protective Coating

The Protective Coating of rebar shall conform with the requirements of the specifications in Table 3-13-2.

**Table 3-13-2 Specifications of Corrosion Protective Coating to Rebar**

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	75
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	40
Tensile Strength	ASTM D638M	N/mm <sup>2</sup>	30
Tensile Shear Bond to Steel	ASTM D1002	N/mm <sup>2</sup>	10
Slant Shear Bond to Mortar	ASTM C882	N/mm <sup>2</sup>	15

#### 3) Zinc Rich Primer

The zinc rich primer to rebar shall be in accordance with the requirements of the specifications in Table 3-13-3.

**Table 3-13-3 Specifications of Zinc Rich Primer for Rebar**

Property	Test Method	Unit	Specifications
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 Film Test	-	%	87.5 ± 2

## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Spalling/Exposed Rebar of Bored Pile**

**PLATE 3 - 13**

**Remedial Measure**

**Filling pile mortar/concrete**

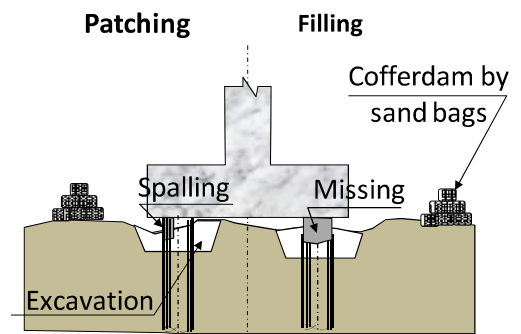
### 5-2 Work requirement

The Contractor shall submit the Methodology Procedures of the Work to the Engineer for his review and approval before commencement of the work.

#### 1) Excavation

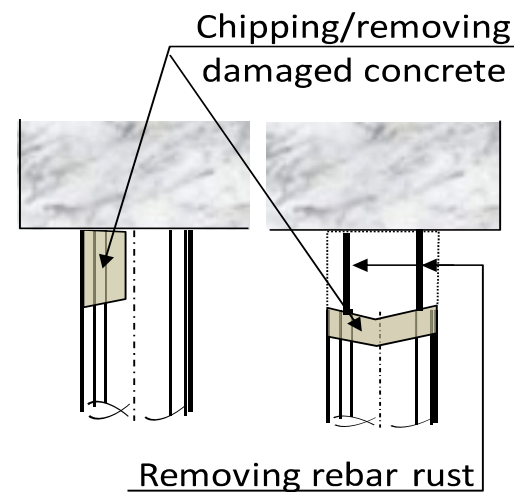
Excavate surrounding soil of the pile until damaged depth plus 20cm.

Temporary cofferdam by such as sand bags and a submersible pump shall be considered, if necessary. With consideration of safety, in case, excavation depth is required deeper than 1.0m, a new pile shall be constructed just nearby the damage pile.



#### 2) Chipping/removing damaged concrete

Damaged concrete shall be removed by chipping works using an electrical jackhammer, chisel. Surface of the concrete shall be clean and dry. Brushing or high-pressed air blowing will be applicable to this work.



#### 3) Removing rust from rebar

Rust of rebar shall be removed by using wire brush. Zinc rich primer shall be applied on the rebar surface after removing rust immediately.

#### 4) Applying Epoxy primer

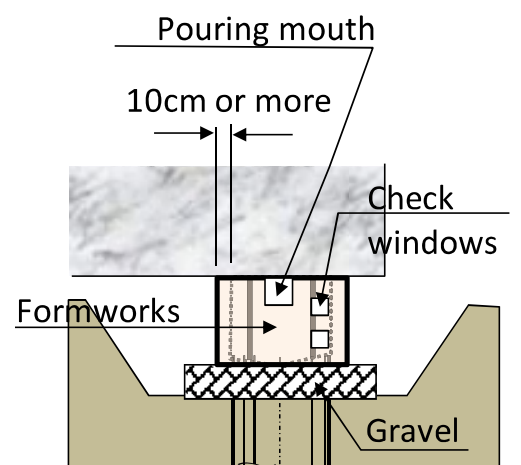
After curing zinc rich primer on rebar, Epoxy primer shall be applied on the concrete and rebar surface under dust and water free condition.

#### 5) Installation of formworks

Patching of pile concrete will not require formworks.

Filling concrete will require formworks which are 10cm or more bigger than the pile radius, however, it is considerable to use surrounding soil wall instead of formwork.

Formworks shall be considered concrete pouring



## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Spalling/Exposed Rebar of Bored Pile**

**PLATE 3 - 13**

**Remedial Measure**

**Filling pile mortar/concrete**

mouth and concrete flow checking windows.

The formworks shall be installed on gravel foundation which protects penetration of soil and mud into the formworks.

6) Applying polymer mortar/Pouring concrete

i) Applying polymer mortar

The mortar should be placed in layers of about 20 mm thickness. Compact each layer thoroughly over the entire surface using a wooden trowel or hammer.

Generally, there should be no time delays between the placing and compacting of layers.

The repair mortar shall be mixed using equipment (normally a force action mixer) of a type approved by the Engineer.

The mixing liquid shall be added to the dry components and thoroughly mixed to achieve a uniform consistency, unless otherwise approved by the Engineer. The mortar shall then be applied to the bonding agent using hand packing and trowel to the satisfaction of the Engineer.

ii) Pouring concrete

A mechanical batch mixer should be used to ensure homogeneity, workability and good board life. Clean, potable water shall be used and the maximum amount added shall be consistent with optimum workability. Hand mixing shall not be permitted unless approved in writing by the Engineer, who should outline hand mixing procedures.

The finished color should not be analyzed until the addition and full mixing of the cement materials and water are complete. Uniform color requires consistent material proportioning.

Concrete/cement mortar shall be pumped through the pour access holes. Spacing for pour access holes shall not exceed 600 mm.



<b>MAJOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Spalling/Exposed Rebar of Bored Pile</b>	<b>PLATE 3 - 13</b>
<b>Remedial Measure</b>	<b>Filling pile mortar/concrete</b>	
<p>Vibrators, placed on the outside face of the formwork, shall be used to achieve proper consolidation. The maximum time allowed between the delivery of grout to the site and the grouting process shall not exceed 60 minutes.</p> <p>1) Curing</p> <p>All types of cement repairs need thorough and continuous curing to develop strength and impermeability, and to minimize drying shrinkage while bond strength is developing. Curing of the repair mortar shall be in accordance with the polymer modified additive manufacturer's instructions.</p> <p>Where curing agents are specified by the manufacturer, they shall be applied immediately after the surfaces have been scarified for the next repair mortar layer or troweled to a finish.</p> <p>2) Remedial work</p> <p>It is anticipated that remaining of some space between top of the pile concrete and the bottom of the pile cap due to sink of concrete. The Contractor shall check exist of space and carries out necessary remedial works such as injection of mortar grout or patching mortar, if space exist. The remedial work methodology shall be included into the Methodology Statement.</p>		
<b>6. Measurement and Payment</b>		
<p>6-1 Method of measurement</p> <p>i) Patching of pile concrete</p> <p>The Engineer will measure the area prepared for Patching pill concrete by the square meter after the identified thickness of surface has been removed. The measured pay quantity will be those areas verified by the Engineer and marked as unsound or delaminated concrete.</p> <p>ii) Filling pile concrete</p> <p>The Engineer will measure the length prepared for Filling pile concrete by the liner meter after the identified length of the pile top has been removed. The measured pay quantity will be those length verified by the Engineer and marked as unsound or delaminated concrete.</p> <p>6-2 Basis of Payment</p> <p>The price and payment per square meter of Patching pile concrete and payment per meter of Filling pile concrete shall include full compensation for removal of deteriorated concrete, surface cleaning and preparation, furnishing and placing all materials, labor,</p>		

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Spalling/Exposed Rebar of Bored Pile</b>	<b>PLATE 3 - 13</b>
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<b>Remedial Measure</b>	<b>Filling pile mortar/concrete</b>
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equipment, tools. It shall also include construction and removal of formworks and other temporary works necessary to complete the Patching pile concrete/Filling pile concrete works.

Pay Item No.	Name	Unit of Measurement
3-13-1	Patching pile concrete	Square Meter (m <sup>2</sup> )
3-13-2	Filling pile concrete	Liner Mater (m)

## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Scouring, Abnormal spacing**

**PLATE 3 - 14**

**Remedial Measure**

**Footing consolidation**

### 1. Work description

**Bridge Scour** is the removal of sediment such as sand and rocks from around bridge abutments or piers. Scour, caused by swiftly moving water, can scoop out *scour holes*, compromising the integrity of a structure. In Bangladesh, bridge scour is one of the main causes of bridge failure, because of river flooding.

Photo 3-14-1 heavy Bridge scour

Photo 3-14-1 typical Bridge scour



If this type of damage is not repaired, it could cause catastrophic failure to the bridge. The typical repair for this type of damage is to place large Rip Rap around the pier (Photo 3-14-3). Projects such as this are difficult to permit because they involve placing equipment and materials in environmentally sensitive areas. Instead of large Rip Rap, Sand Bags are used often for the emergency remedial measure (Photo 3-14-4).

Photo 3-14-3 Placing Rip Rap



Placing Special Heavy Loose Rip Rap

Photo 3-14-4 Placing Sand Bags



## MAJOR REPAIR METHODS

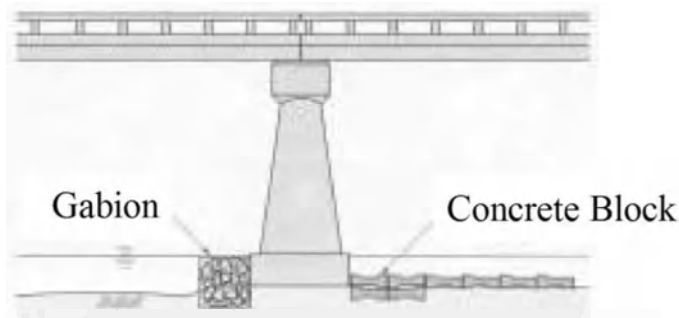
<b>Defect/Deficiency</b>	<b>Scouring, Abnormal spacing</b>	<b>PLATE 3 - 14</b>
<b>Remedial Measure</b>	<b>Footing consolidation</b>	

### 2. Application criteria

Placing Rip Rap/Sandbags are mainly applied for emergency remedial measures. Once a bridge is evaluated as scour critical, the bridge owner should prepare a scour plan of action to mitigate the known and potential deficiencies. The plan may include installation of countermeasures, inspections after flood events, and procedures for closing bridges if necessary.

As one of the countermeasures of Bridge Scour, Footing Consolidation is effective. Examples are shown in the Figure 3-14-1. However, by the selection of remedial measure, detailed investigation should be executed.

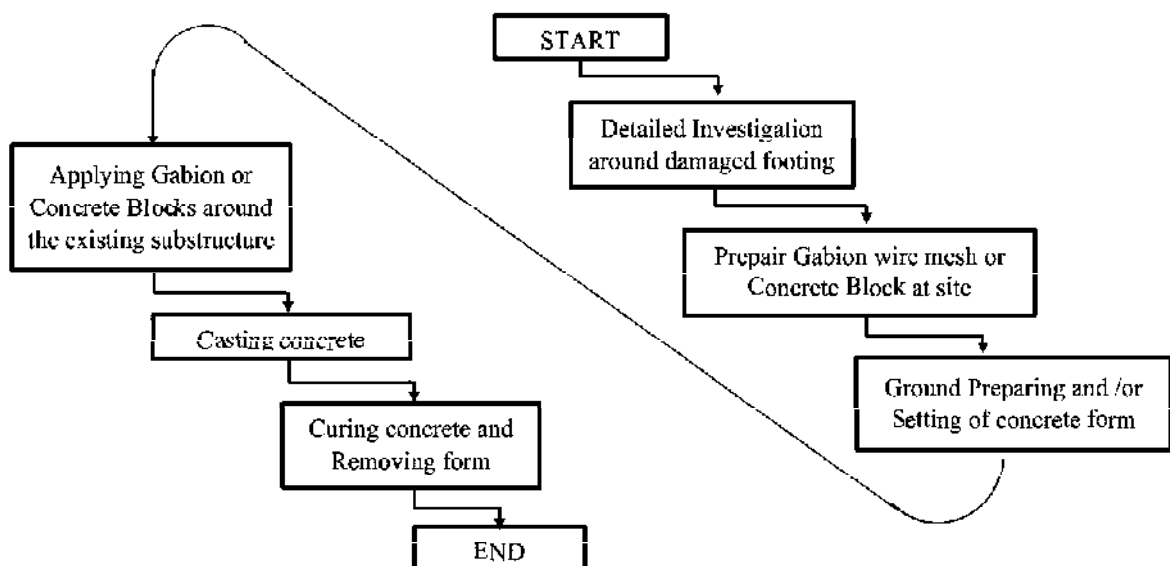
Figure 3-14-1 Examples of Footing Consolidation



### 3. Work sequence

Work sequence of Footing consolidation method for scoured substructure is as shown in Figure 3-14-2.

Figure 3-14-2 Work sequence



**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Scouring, Abnormal spacing</b>	<b>PLATE 3 - 14</b>
<b>Remedial Measure</b>	<b>Footing consolidation</b>	

**4. Required Equipment/Tool and Material**

4-1 Equipment/Tools

Following Equipment is necessary for consolidation of footing;

- Wire cutter
- Pliers and hand tools for binding of steel wires
- Cleaning equipment comprising hand tools, shovel, and any other tool
- Truck crane
- Concrete mixer and Form installation tool

4.2 Material

Following Materials are necessary for consolidation of footing;

- Wire mesh
- Wires for tying
- Infill materials such as stones, bricks, concrete blocks
- Cement, sand, aggregate, water
- Form

**5. Requirement, Specification**

5.1 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.

1) Inspection

Inspect and identify all deteriorated and damaged parts of the existing footing protection work such as gabion or concrete blocks.

2) Preparation of work

Proper access arrangement for the work shall be ensured.

Removing damaged gabion or/and concrete blocks.

Carefully cut and remove the damaged/unacceptable portions of the gabion wires.

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Scouring, Abnormal spacing</b>	<b>PLATE 3 - 14</b>
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<b>Remedial Measure</b>	<b>Footing consolidation</b>
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While removing the damaged wires, care shall be exercised not to disturb the existing portion of the gabion work which is in intact condition.

3) Filling missing material

Any missing infill material (stones/bricks/concrete blocks) shall be replaced by the approved infill material by the Engineer as per the specification. 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.

4) Casting new concrete

If casting of new concrete is approved, form work is done before the casting.  
Before the casting work, the casting level of form work shall be kept above the water level, otherwise the use of Underwater concrete is required.

5) Curing concrete

Curing duration depends on the used cement type and admixture of concrete. Curing duration is approved by the Engineer in Charge. Then form work will be removed.

Upon completion of works, remove all material, tools and equipment from the site.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	Scouring, Abnormal spacing	<b>PLATE 3 - 14</b>
<b>Remedial Measure</b>	Footing consolidation	

### 6. Measurement and Payment

**6-1 Method of Measurement**

This works will be measured by square meter or cubic meter for sites described on the plans.

**6.2 Basis of payment**

The contract price paid per square meter or cubic meter for this work shall include full compensation for all labor, materials, tools, equipment, and other incidental expenses, and for executing the works.

Pay Item No.	Name	Unit of Measurement
3-14-1	Footing consolidation	Square meter (m <sup>2</sup> )
3-14-2	Footing consolidation	Cubic meter (m <sup>3</sup> )

## MAJOR REPAIR METHODS

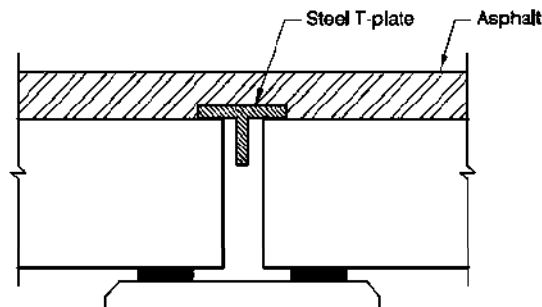
<b>Defect/Deficiency</b>	Water Leakage/Puddle at Expansion Joint	<b>PLATE 3 - 15</b>
<b>Remedial Measure</b>	Replacement of small joint	

### 1. Work description

The quality and maintenance of the expansion joints are vital to the behavior of the bridges and its durability. Accordingly, it should be ensured that expansion joints are waterproofed as well as resistant to leakage. In the case of Asphaltic plug joint, the sealant asphalt is easily damaged due to traffic load and aging.

The usual gap of concrete edge is around 20 mm considering temperature here in the Bangladesh as  $35^{\circ}\text{C} \sim 7^{\circ}\text{C}$  ( $=21^{\circ}\text{C} \pm 14^{\circ}\text{C}$ ). The movement of the bridge span is  $12 \times 10^{-6} / ^{\circ}\text{C} \times 20 \text{ m} \times (\pm 14^{\circ}\text{C}) = \pm 3.4 \text{ mm}$ , if the span length is 20m. Otherwise, the movement by traffic load is approximately less than 5 mm. Total movement of the usual span RC deck slab is below  $\pm 10 \text{ mm}$ . With these considerations, the most suitable repair measure for damaged small joint type is the installation of Buried joint with steel T-plate (Figure 3-15-1). However, Water leak between the steel T-plate and the gap should be avoided.

Figure 3-15-1 Buried joint with steel T-plate



**Damaged Asphaltic plug joint**



**After removing Sealant of Asphaltic plug joint**



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Water Leakage/Puddle at Expansion Joint</b>	<b>PLATE 3 - 15</b>
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<b>Remedial Measure</b>	<b>Replacement of small joint</b>
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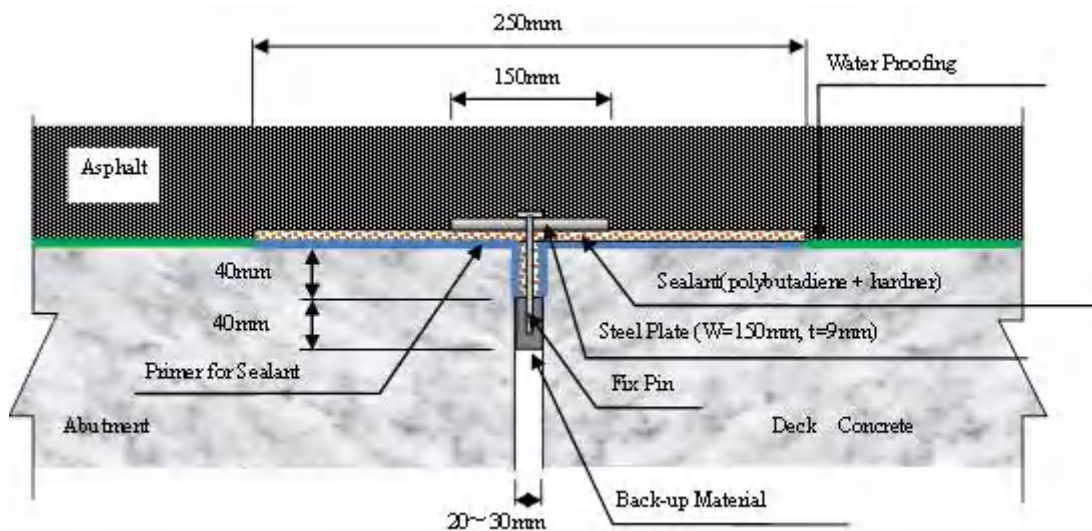
### 2. Application criteria

Buried joints with steel T-plate are mainly applied on RC deck slab bridges and steel girder bridges on fixed bearings. The former small joint such as Asphaltic plug joint is repaired if the following conditions are rated as “Bad” as per suggested condition rating criteria:

- Water leakage: detected area >50%
- Abnormal Space/ Noise: Detected
- Difference in Elevation: >30mm at expansion gap
- Deteriorated Sealant: Pourable joint sealant almost completely lost.

To improve the durability of the Buried joint, the following modified Buried joint is shown in Figure 3-15-2. Modification is achieved using polybutadiene Sealant on the bridge deck surface under the asphalt layer and Backup material for the gap.

Figure 3-15-2 modified Buried joint with steel T-plate



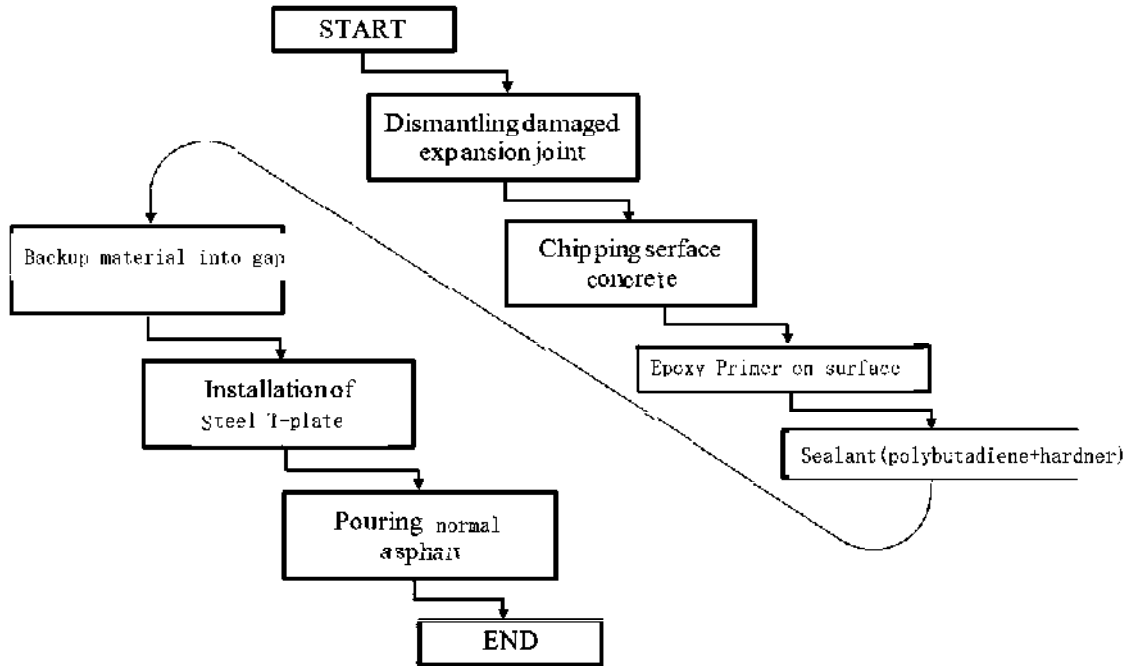
### 3. Work sequence

Work sequence of replacement method of small joint to the modified Buried joint with steel T-plate is as shown in Figure 3-13-3.

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Water Leakage/Puddle at Expansion Joint</b>	<b>PLATE 3 - 15</b>
<b>Remedial Measure</b>	<b>Replacement of small joint</b>	

Figure 3-15-3 Work sequence



**4. Required Equipment/Tool and Material**

**4-1 Equipment/Tools**

Following Equipment is necessary for replacement of the Sealant asphalt joint;

- Concrete Cutter
- Electric impact hammer/small jackhammer
- Gas burner
- Asphalt mini cooker
- Surface finisher

**4.2 Material**

Following Materials are necessary for replacement of the Sealant asphalt joint;

- Steel Plate (w=150 mm, t=9 mm) with Fix pin
- Epoxy primer
- Sealant (polybutadiene + Hardener)
- Backup material for gap
- Normal Asphalt

<b>MAJOR REPAIR METHODS</b>		
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<b>Defect/Deficiency</b>	<b>Water Leakage/Puddle at Expansion Joint</b>	<b>PLATE 3 - 15</b>
<b>Remedial Measure</b>	<b>Replacement of small joint</b>	

<b>5. Requirement, Specification</b>
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**5.1 Material**

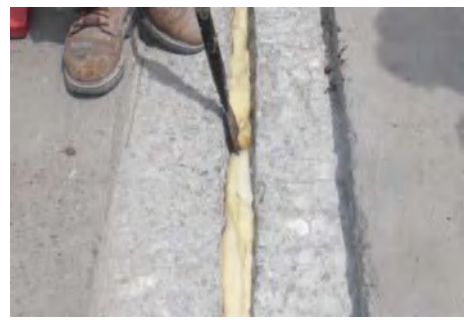
The material shall be approved by the Engineer through mill certificate of the supplier.

- 1) Steel plate  
Pre-fabricated steel plate shall conform to ASTM A36 or equivalent.
- 2) Normal asphalt  
Asphalt compound shall conform to the requirements of the Table 2-5-1 of Plate 2-5 or equivalent.
- 3) Epoxy primer
- 4) Sealant  
Polybutadiene Sealant + Hardener
- 5) Backup material  
A compressive material used to fill the joint gap.

**5.2 Works requirement**

The Contractor shall submit shop drawings for the modified Buried joint and the Methodology Statement of the Work to the Engineer for his review and approval.

- 1) Dismantle Existing Damaged Asphalt Joint Sealant  
The damaged sealant due to heavy traffic, aging, etc. shall be dismantled.
- 2) Chipping surface concrete  
The surface of concrete at the location of the existing damaged joint shall be chipped off for purposes of installing new steel plate with fix pin.



## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Water Leakage/Puddle at Expansion Joint**

**PLATE 3 - 15**

**Remedial Measure**

**Replacement of small joint**

3) Applying of Epoxy Primer and Sealant

The contractor shall submit shop drawing to be approved by the Engineer, prior to the installation of the steel plate.

4) Installation of Backup material

Backup material shall be inserted to prevent the binder leaking from the joint during the filling of the joint.



5) Installation of Steel plate

The contractor shall submit shop drawing to be approved by the Engineer, prior to the installation of the steel plate with fix pin.

6) Pouring normal asphalt

The normal asphalt shall be subjected to strict quality control especially for the temperature control requirements. Using mini asphalt cooker, normal asphalt shall be cooked until it reaches 180°C.

Traffic operations can resume after the Asphalt temperature is cooled down to 40°C.



<b>MAJOR REPAIR METHODS</b>		
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<b>Defect/Deficiency</b>	<b>Water Leakage/Puddle at Expansion Joint</b>	<b>PLATE 3 - 15</b>
<b>Remedial Measure</b>	<b>Replacement of small joint</b>	

<b>6. Measurement and Payment</b>
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6-1 Method of Measurement

The method of measurement for Replacement of the small expansion joint such as Asphaltic Plug joint into the Buried joint shall be measured by linear meter of joint length shown in the drawings including approved shop drawings.

6.2 Basis of payment

The contract price paid per liner meter for this joint shall include full compensation for furnishing all labor, materials, tools, equipment, and other incidental expenses, and for executing the works. The steel components, flexible asphalt and repair works shall be deemed included in the price per linear meter.

Pay Item No.	Name	Unit of Measurement
3-15	Replacement of small expansion joint	Linear Meter (m)

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Abnormal Spacing at Expansion Joint</b>	<b>PLATE 3 - 16</b>
<b>Remedial Measure</b>	<b>Replacement of Steel joint</b>	

### 1. Work description

The quality and maintenance of the expansion joints are vital to the behavior of the bridges and their durability. Accordingly, it should be ensured that expansion joints are waterproofed as well as resistant to leakage.

When water leakage occurs at expansion joints, dirt, soil, gravel and water are collected on the bearing seat locations. This condition will initiate corrosion of steel members including the steel bearings, bottom flanges at ends of steel girder and steel connection accessories.

This repair method is intended for damaged steel type and rubber type expansion joints, which would be replaced with suitable water-proof type expansion joints.

Concrete cutter shall be used to cut both joint edges of the concrete surface to form a straight cutting line pattern. The defective expansion joint shall then be dismantled after chipping off the concrete with an electric jack hammer. The new expansion joint shall be installed with its top level matching the required finish surface. Concrete/grout shall be finally poured, leveled, and then cured.

Photo 3-16-1 and 3-16-2 shows example of water proof type steel expansion joint

Photo 3-16-1 Structure of the Steel Expansion Joint



Photo 3-16-2 After installation



### 2. Application criteria

Replacement of the steel expansion joint shall be implemented depending on condition of the expansion joint obtained through Bridge Condition Survey and daily maintenance activities or information from road users.

Following conditions can be referred as one of the Standards for decision of replacement of the steel expansion joint.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Abnormal Spacing at Expansion Joint</b>	<b>PLATE 3 - 16</b>
<b>Remedial Measure</b>	<b>Replacement of Steel joint</b>	

- Water leakage: detected area >50%
- Abnormal Space/ serious Noise: Detected
- Difference in Elevation: >30mm at expansion gap

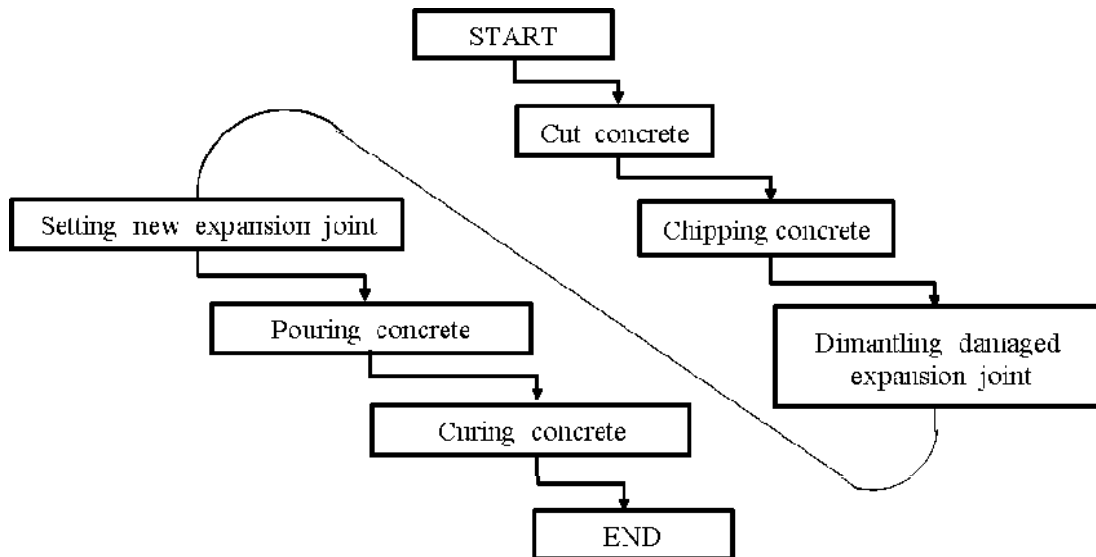
Meanwhile, followings can be referred as Standards for decision of replacement of the rubber expansion joint:

- Water leakage: detected area >50%
- Abnormal Space/ Noise: Detected
- Difference in Elevation: >30mm at expansion gap
- Rubber seal dislodge or rupture: detected area >50%
- Deteriorated Sealant: Pourable joint sealant maybe almost lost off from location

### 3. Work sequence

Work sequence of replacement method of the Steel/Rubber expansion joint is as shown in Figure 3-16-1.

Figure 3-16-1 Work sequence



### 4. Required Equipment/Tool and Material

4-1 Equipment/Tool

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Abnormal Spacing at Expansion Joint</b>	<b>PLATE 3 - 16</b>
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<b>Remedial Measure</b>	<b>Replacement of Steel joint</b>
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Following equipment/tool will be required for replacement works of the expansion joint.

- Concrete Cutter
- Electric impact hammer/small jackhammer
- Electric concrete vibrator
- Trowel

#### 4-2 Material

- New Expansion Joint with water proof rubber
- Rebar (16 mm dia.)
- Concrete/grout

### 5. Requirement, Specification

#### 5-1 Material

For new expansion joint

- Steel plates, anchor bars: ASTM A36 or equivalent
- Mortar/concrete: refer to Plate 3-3 Polymer cement mortar

The expansion joint rubber seal shall comply with the following specifications:

Table 3-16-1 Specification of Expansion Joint Rubber Seal

Property	Test Method	Unit	Specification
Tensile Strength	ASTM D 412	MPa	0.98(Min)
Elongation at break	ASTM D 412	%	100(Min)

The type and size of rubber seal for expansion joint should be determined based on manufacturer's instructions. The material test shall be applied for Tensile strength and Elongation to be approved by the Engineer.

#### 5-2 Work requirement

##### (1) Cut concrete surface

The Contractor shall submit for Engineer's approval, shop drawings for the new water-proofing type expansion joint and the construction plan for the dismantling and installation.

With a concrete cutter device, limits of concrete to be demolished near the existing expansion joints shall be defined in the transverse direction of the bridge deck (300 mm at each edge of the expansion gap).

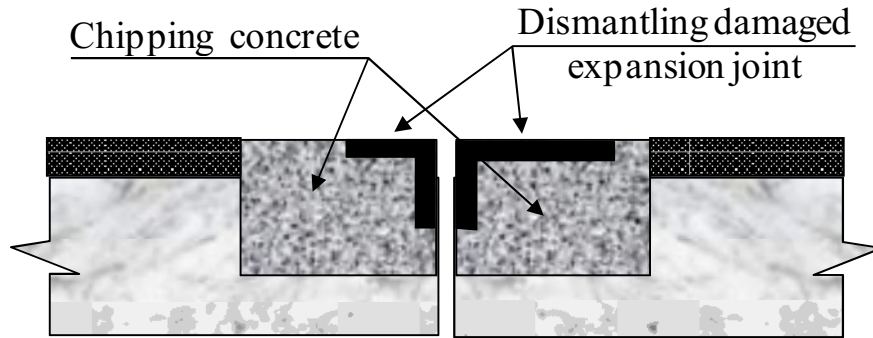
##### (2) Chip off concrete and Dismantle Expansion Joint

Based on the defined limits, the Contractor shall chip-off further the concrete with a jack hammer to expose the defective joint and portions of the existing reinforcement. After chipping off is accomplished, existing expansion joint material shall be removed

## MAJOR REPAIR METHODS

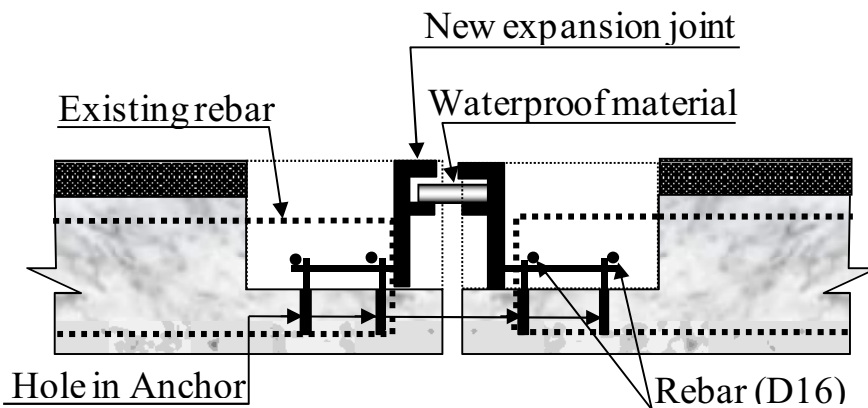
<b>Defect/Deficiency</b>	Abnormal Spacing at Expansion Joint	<b>PLATE 3 - 16</b>
<b>Remedial Measure</b>	Replacement of Steel joint	

from its location.



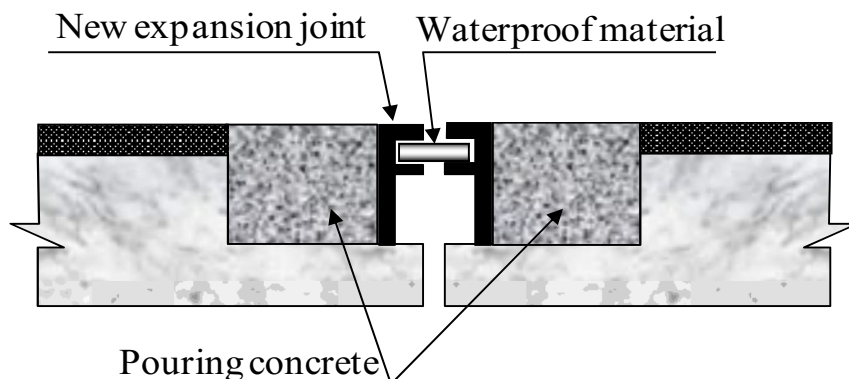
### (3) Set up new expansion joint

The new expansion joint shall be installed to proper position considering the required finish level of the deck. The contractor shall submit for Engineers approval, result of measurement verifications for the proposed installation.



### (4) Pouring concrete

The contractor shall submit for Engineer's approval, material test results of concrete. After approval, the contractor shall commence pouring of the concrete at identified locations near the new expansion joint. Final concrete shall be finished using trowel and shall be subjected to curing process.



**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Abnormal Spacing at Expansion Joint</b>	<b>PLATE 3 - 16</b>
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<b>Remedial Measure</b>	<b>Replacement of Steel joint</b>
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**6. Measurement and Payment**

6-1 Method of Measurement

The method of measurement for this method shall be by linear meter of joint length which will be defined by the Engineer.

6-2 Basis of Payment

The contract price paid per liner meter of seamless joint shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for executing all related works.

Pay Item No.	Name	Unit of Measurement
3-16-(1)	Replacement of Steel Expansion Joint	Linear Meter (m)
3-16-(2)	Replacement of Rubber Expansion Joint	Linear Meter (m)

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence on Deck Slab</b>	<b>PLATE 3 - 17</b>
<b>Remedial Measure</b>	<b>Waterproofing – Liquid Type</b>	

### 1. Work description

Concrete is naturally alkaline and therefore protects the steel. However, the effect of its contact with water and corrosive materials reduces the alkaline environment and allows an electrolytic process to start, thus corroding the rebar. The result of the corrosion and rusting is to expand the rebar which then damages and eventually destroys the surrounding concrete of the deck. The primary protection against this destructive damage is through installation of waterproofing membrane on the deck slab.

There are two bridge deck waterproofing methods i.e. **Sheet method** and **Liquid method**. The Sheet method is the recommendable method from the perspective of durability under traffic load, however need well trained technician and higher costs.

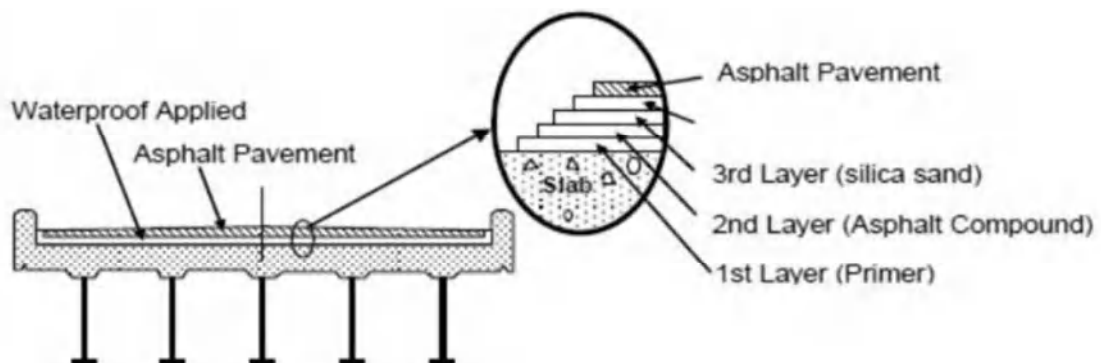
The Liquid Method consists of two types, namely: Rubberized Membrane Method (Photo 17-1) and **Asphalt Compound Method** (Photo 17-2).

**Photo 17-1 Rubberized Membrane Method**

**Photo 17-2 Asphalt Compound Method**



**Figure 3-17-1 Sectional Component of Asphalt Compound Method**



**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence on Deck Slab</b>	<b>PLATE 3 - 17</b>
<b>Remedial Measure</b>	<b>Waterproofing – Liquid Type</b>	

**2. Application criteria**

The Rubberized Membrane Method mainly involves use of chloroprene rubber. The **Asphalt Compound Method** meanwhile involves use of asphalt mixed with special rubber, which is melted in a mechanically agitated heating process.

Features of both methods are summarized below:

(1) Rubberized membrane Method

- ✓ Application procedure is very simple and final product is proven to have good performance.
- ✓ Cost is higher than Asphalt Compound Method.
- ✓ In cases where removal of asphalt from deck is required (difficult to remove completely), this method would not be ideal since the roughness of the deck surface, reduces its waterproofing efficiency.

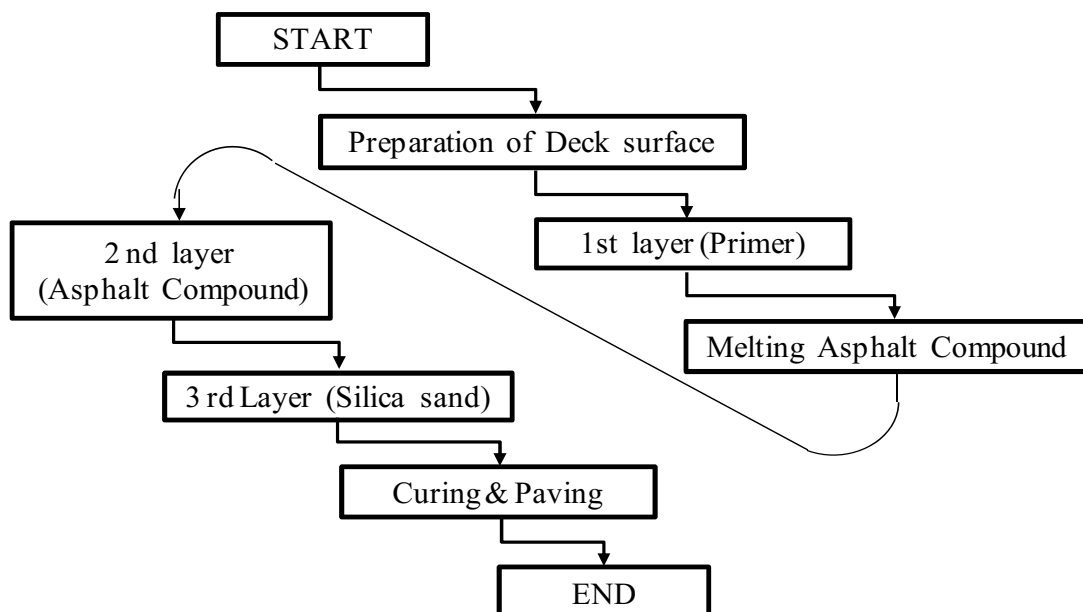
(2) Asphalt Compound Method

- ✓ Less costly materials.
- ✓ Equipment costs such as kettle and heating tool, including its inland transport cost tend to increase construction cost.

**3. Work sequence**

Work sequence of Asphalt Compound Method is as shown in Figure 3-17-2.

**Figure 3-17-2 Work sequence**



## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence on Deck Slab</b>	<b>PLATE 3 - 17</b>
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<b>Remedial Measure</b>	<b>Waterproofing – Liquid Type</b>
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### 4. Required Equipment/Tool and Material

#### 4-1 Equipment/Tools

The following Equipment is necessary for Asphalt Compound Waterproofing Method:

- Kettle with Heater
- Roller Brush or Hair brush
- Rubber Brush

#### 4-2 Material

- Primer
- Asphalt Compound Membrane
- Silica sand

### 5. Requirement, Specifications

#### 5-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier  
Primer, tack coat and silica sand are in accordance with DPWH Standard Specifications.

##### 1) Primer

Primer specifications shall be similar to those required for rubberized membrane.

##### 2) Asphalt Compound

Waterproofing by asphalt compound membrane shall conform to the requirements of the specifications shown in Table 3-17-1, or equivalent ASTM Specifications.

**Table 3-17-1 Specification of Asphalt Compound**

Property	Test Method	Unit	Specification
Penetration with Conic Needle	ASTM D217	mm	2 ~ 5
Melting Temperature	ASTM D3461	°C	80
Elongation	ASTM D 638	%	3.5
Tensile Strength	ASTM D 638	Kgf/cm <sup>2</sup>	300

#### 5-2 Work Requirement

The Contractor shall submit shop drawings for the waterproofing application, slab drain and spray mesh and the Methodology Statement of the Work to the Engineer for his review and approval. The performance test for waterproofing shall be applied by contractor to be approved by the Engineer.

##### 1) Surface preparation

The deck concrete, including curbs, and sidewalks

## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Water Leakage/Efflorescence on Deck Slab**

**PLATE 3 - 17**

**Remedial Measure**

**Waterproofing – Liquid Type**

must be completely dry and cured at least 14 days before application of primer or membrane. The existing surface of the concrete shall be completely sandblasted or shot-wire brushed to expose sound, laitance-free concrete. All dirt and debris shall be removed and disposed of, leaving a prepared surface satisfactory for primer coating. Primer coating and waterproofing shall not commence until the Engineer has accepted all preparation works.



If the existing asphalt pavement is covered on the deck slab, the pavement shall be stripped-off totally using pavement scraper.

2) Primer coat

Prior to the application of the primer coat, the concrete surface shall be air blasted to remove all dust and any other foreign materials. Primer coat material shall be applied with approved equipment which will provide uniform application at the required rate.



The primer coat shall be applied only when the concrete is dry and clean, and when the air and concrete surface temperatures are above 10°C. Waterproofing equipment or material shall not be permitted on the primer coat until it has fully cured and is completely tack-free.

3) Melting Asphalt Compound

Asphalt compound shall be melted in the mechanically agitated heating tool and mixed in a kettle. This unit shall keep the contents continuously agitated until the material can be drawn free flowing and lump-free from the mixing unit at a temperature recommended by the manufacturer.



An approved heating and mixing kettle shall be used to heat the hot-applied rubberized asphalt membrane. The kettle shall be of a double boiler oil transfer type with a built-in agitator. It shall be equipped with permanently installed dial type thermometers to measure the temperature of the melted compound and the oil.

4) Application of Asphalt Compound

Asphalt Compound shall not be applied until the primer has cured completely. The

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence on Deck Slab</b>	<b>PLATE 3 - 17</b>
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<b>Remedial Measure</b>	<b>Waterproofing – Liquid Type</b>
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asphalt membrane shall be applied within the temperature range recommended by the manufacturer, to the clean, primer-coated concrete deck, to form a uniform film having a minimum thickness of 4 mm ~ 6 mm (Approximately 3-2kg/m<sup>2</sup>). The laying operation shall be such that discontinuities in the membrane are avoided and any joints lapped 150 mm.



The membrane shall be applied over all the waterproofed joints and cracks, and shall extend up to the face of curbs, medians, barrier walls, and deck drains, to the height of the top of the hot mix surface course. Deck drains and drainage tubes shall be covered.

5) Spreading Silica Sand for protection

Silica sand shall be spread as protection to the waterproofing layer, while the membrane on the deck is still hot. Excess silica sand shall be removed by broom. The silica sand to be used shall be approximately 0.7 kg/m<sup>2</sup>. (Refer to the Manufacturer's instructions)



### 6. Measurement and Payment

6-1 Method of Measurement

Deck slab waterproofing membrane by Asphalt Compound Method, complete in place and accepted, will be measured by square meters of bridge deck. Material placed on curb faces and overlaps will not be measured. Tack coat and asphalt overlay will be measured and paid for as provided under the respective items specified in the RHD Standard Specification.

6-2 Basis of payment

Payment for deck waterproofing by Asphalt Compound Method will be made at a unit price bid per square meter of deck waterproofed, which shall cover full compensation for the cost of all labor, equipment and materials required for the preparation of the concrete deck surface including sandblasting, supply and application of the tack coat, asphalt membrane, rubber membrane and protection board, handling and controlling of traffic, and for all other work items necessary for the satisfactory completion of the work.

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Water Leakage/Efflorescence on Deck Slab</b>	<b>PLATE 3 - 17</b>
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<b>Remedial Measure</b>	<b>Waterproofing – Liquid Type</b>
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Pay Item No.	Name	Unit of Measurement
3-17	Waterproofing Asphalt Compound Method	Square Meter (m <sup>2</sup> )

**MINOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Functional disorder bearing</b>	<b>PLATE 3-18</b>
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<b>Remedial Measure</b>	<b>Repainting of steel bearing</b>
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**1. Work description**

Due to thin paint coverage on steel surfaces or formation of pin-holes in paint, the steel surface may get exposed to atmosphere resulting in initiation of corrosion. Due to corrosion, the sliding function of steel bearing is inhibited. Therefore, cleaning of corrosive surface and repainting is important to improve the sliding function of bearing.

Work included in this section comprises field painting on steel members at localized areas including surface preparation and other associated works. This section covers only painting on relatively small affected areas which can be carried out with the use of small power tools / hand tools. Painting of larger areas or many steel bearings requiring sand blast cleaning should be carried out in accordance with the specifications.

**2. Application criteria**

Repainting of steel bearing shall be done locally on partially rusted steel surfaces. Depending on the area affected by corrosion, two different surface preparations have been suggested :

**Table 3-18-1 Degree of rusting and surface preparation**

Affected area	Description of degree of rusting	Surface preparation	Reference Photos of surface preparation	
			Before	After
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	Photo4-1	Photo4-3
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	Photo4-2	Photo4-4

**Steel surfaces affected by corrosion**

Photo18-1 Surface area of 10~20% rusting



Photo18-2 Surface area of 20~30 rusting



MINOR REPAIR METHODS		
Defect/Deficiency	Functional disorder bearing	PLATE 3-18
Remedial Measure	Repainting of steel bearing	

### Corrosion affected steel surfaces after surface preparation

Photo18-3 Less severe corrosion



Photo18-4 More severe corrosion



If the paint condition is identified as Grade-1 (affected surface 10-20%), aluminum paint shall be applied with a similar shade.

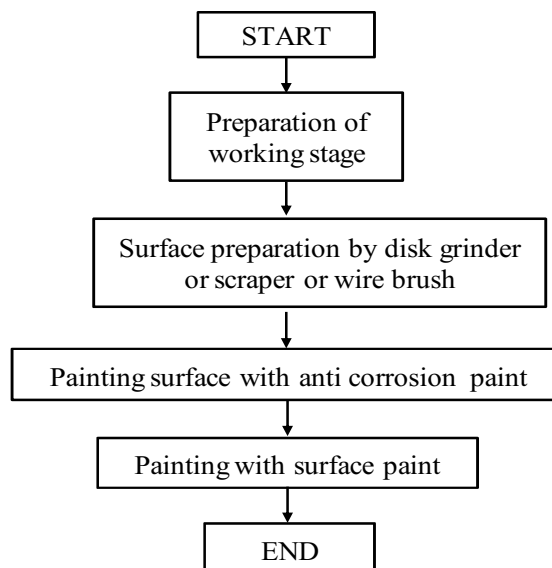
Where condition of paint is evaluated as Grade-2 (affected surface 20-30%) with loss of section within 20%, special anticorrosion paint shall be applied to restrict corrosion from progressing further.

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. As shown in the photos, special anticorrosion paint shall be applied to heavily corroded steel portions.

### 3. Work sequence

Work sequence of Epoxy Coating is as shown in Figure 2-4-1.

**Figure 2-4-1 Work sequence**



<b>MINOR REPAIR METHODS</b>														
<b>Defect/Deficiency</b>	<b>Functional disorder bearing</b>	<b>PLATE 3-18</b>												
<b>Remedial Measure</b>	<b>Repainting of steel bearing</b>													
<b>4. Required Equipment/Tool and Material</b>														
<p>4.1 Materials</p> <ul style="list-style-type: none"> <li>- Aluminum paint / special anticorrosion paint as required</li> <li>- Thinner</li> <li>- Epoxy resin filler</li> </ul> <p>4.2 Tools/Equipment/</p> <ul style="list-style-type: none"> <li>- Scaffolding, inspection vehicle</li> <li>- Portable generator (3 kVA)</li> <li>- High pressure water blaster (8.0Mpa, 10.0 liters/min.)</li> <li>- Sandpaper, portable power disk grinder</li> <li>- Paint brush, roller</li> </ul>														
<b>5. Requirement, Specification</b>														
<p>5-1 Material</p> <p>Aluminum paint material shall be in accordance with the manufacturer's specifications and as approved by the Engineer.</p> <p>For special anticorrosion paint, the materials shall satisfy the test requirements indicated in the relevant ASTM specifications as follows:</p> <p style="text-align: center;"><b>Table 2-4-2 Specification of Aluminum paint</b></p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th style="text-align: center;">Tests</th> <th style="text-align: center;">Test Reference</th> <th style="text-align: center;">Specifications</th> </tr> </thead> <tbody> <tr> <td>Adhesive test</td> <td>ASTM D7234</td> <td>7days 1.0 N/mm<sup>2</sup>, 28days 1.5 N/mm<sup>2</sup></td> </tr> <tr> <td>Elongation</td> <td>ASTM C190</td> <td>7days 0.40 %, 28days 0.40 %</td> </tr> <tr> <td>Saltwater test</td> <td>ASTM D6943</td> <td>No defection</td> </tr> </tbody> </table> <p>5-2 Work requirement</p> <p>1) Scaffolding</p> <p>Scaffolding shall be installed for close access to the corrosion affected surfaces of the steel bearings 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.</p>			Tests	Test Reference	Specifications	Adhesive test	ASTM D7234	7days 1.0 N/mm <sup>2</sup> , 28days 1.5 N/mm <sup>2</sup>	Elongation	ASTM C190	7days 0.40 %, 28days 0.40 %	Saltwater test	ASTM D6943	No defection
Tests	Test Reference	Specifications												
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Saltwater test	ASTM D6943	No defection												

<b>MINOR REPAIR METHODS</b>		
<b>Defect/Deficiency</b>	<b>Functional disorder bearing</b>	<b>PLATE 3-18</b>
<b>Remedial Measure</b>	<b>Repainting of steel bearing</b>	
<p>2) Preparation of Steel Surface:</p> <p>Surface preparation shall conform to the paint manufacturer's specifications. Hand or power tools shall be applied for cleaning the surface</p> <p>Groves 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.</p> <p>Application of aluminum paint material shall be in accordance with the manufacturer's specifications and as approved by the Engineer.</p> <p>3) Application of Paint</p> <p>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.</p> <p>Total dry film thickness for special anticorrosive paint shall be 500<math>\mu</math> m (equivalent 1.5kg/m<sup>2</sup>) consisting of two layers of coating as follows:</p> <ul style="list-style-type: none"> <li>- Layer-1: 250<math>\mu</math> m</li> <li>- Layer-2: 250<math>\mu</math> m</li> </ul> <p>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 <math>\mu</math> m.</p> <p>Royal paint is recommended for galvanized member touchup painting.</p> <p>Total dry film thickness for Royal paint shall be 80<math>\mu</math> m (equivalent 0.5kg/m<sup>2</sup>) consisting of two layers of coating as follows:</p> <ul style="list-style-type: none"> <li>- Layer-1: 40<math>\mu</math> m</li> <li>- Layer-2: 40<math>\mu</math> m</li> </ul> <p>Royal paint shall be applied in accordance with the stipulations of paint manufacturer's specifications.</p>		

MINOR REPAIR METHODS		
Defect/Deficiency	Functional disorder bearing	PLATE 3-18
Remedial Measure	Repainting of steel bearing	

## 6. Measurement and Payment

### 6.1 Method of Measurement

The work shall be measured as the accepted surface area treated and painted, in square meters.

### 6.2 Basis of Payment

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 Item No.	Name	Unit of Measurement
2-4	Repainting of steel bearing	Square Meter (m <sup>2</sup> )

**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Difference in Level due to Defect of Bearing</b>	<b>PLATE 3 - 19</b>
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<b>Remedial Measure</b>	<b>Replacement of Rubber Bearing</b>
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**1. Work description**

Function of a bearing shoe is transferring all load from a superstructure including own load of the superstructure to a substructure such as an abutment and a pier.

In case the bearing shoe has some defect, a road surface will lose its flatness and causes impact to both of the superstructure and substructures. This impact will to be a cause of damages to the superstructure and substructures.

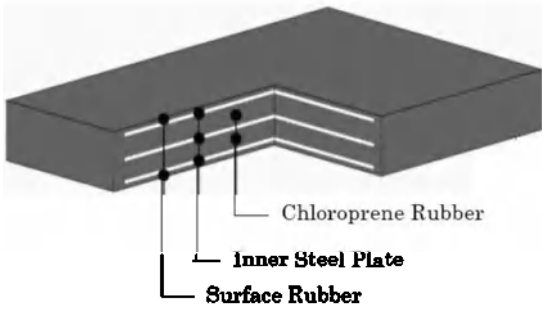
Meanwhile, rusting condition of the bearing shoe area is one of the most serious areas due to narrow space and concentration of debris and water.

Effective service life of elastomeric bearings is estimated to be 15 – 25 years. As the material ages during its serviceability period, it exhibits severe bulging or cracking. These are signs that the elastomeric bearings need to be replaced.

Replacement with new bearing shoe should be performed strictly in accordance with the relevant technical requirements and recommendations provided by the bearing manufacturers.

Installation should be performed by highly experienced staff subject to close supervision.

Usually, the jack-up girder technique is utilized to allow for replacement of bearings. During replacement of the bearings, traffic may remain opened but with imposed restriction on passing speed as safety precaution. The girder shall be jacked up to around 5 mm to 10 mm, with one jack stroke.



**2. Application criteria**

Replacement of bearing shall be implemented if existing rubber bearings already exhibited severe cracks and abnormal bulging. Old steel bearings need to be replaced especially if loose connections were found.

The capacity of the new bearing should be the same as the old bearing, subject to approval of the Engineer.

## MAJOR REPAIR METHODS

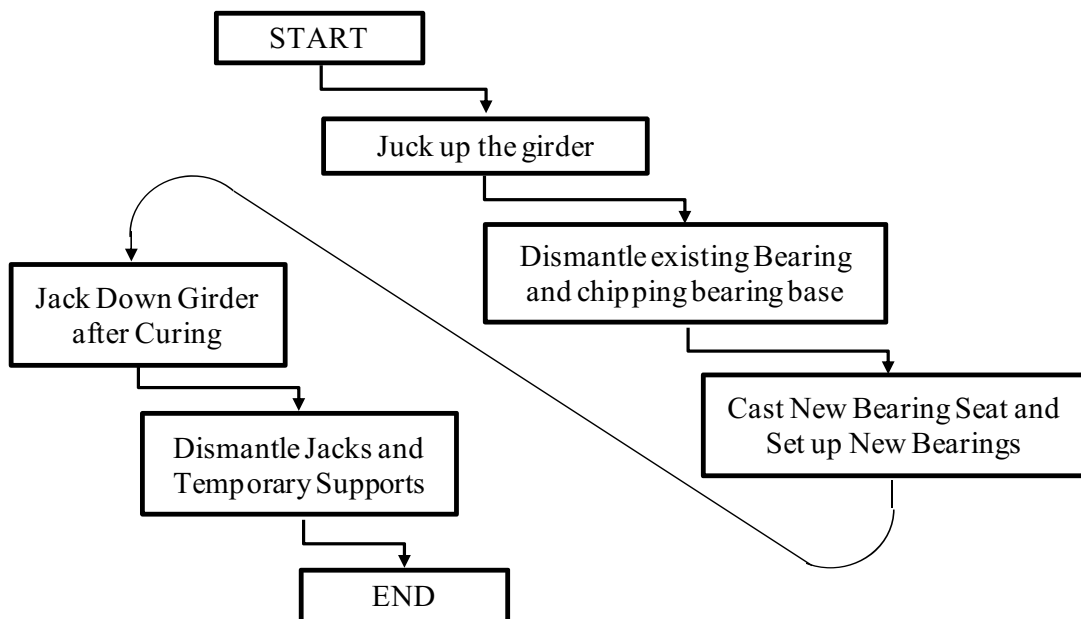
<b>Defect/Deficiency</b>	<b>Difference in Level due to Defect of Bearing</b>	<b>PLATE 3 - 19</b>
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<b>Remedial Measure</b>	<b>Replacement of Rubber Bearing</b>
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### 3. Work sequence

Work sequence of replacement method of the Rubber bearing shoe is as shown in Figure 3-19-1.

Figure 3-19-1 Work sequence



### 4. Required Equipment/Tool and Material

#### 4-1 Equipment/Tool

Following tools/equipment will be required for replacement works of the bearing shoe.

- Hydraulic Jack
- Electrical Jackhammer
- Portable generator
- Trowel

#### 4-2 Material

Following tools/equipment will be required for replacement works of the bearing shoe.

- Elastomeric bearing pads.
- Rebar
- Mortar/concrete

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Difference in Level due to Defect of Bearing</b>	<b>PLATE 3 - 19</b>
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<b>Remedial Measure</b>	<b>Replacement of Rubber Bearing</b>
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### 5. Requirement, Specification

#### 5.1 Material

##### (1) Bearing Pads

Elastomeric bearing pads shall be confirmed to AASHTO M251.

Property	Test Method	Unit	Specification
Hardness, Durometer	ASTM D 2240	—	60±5

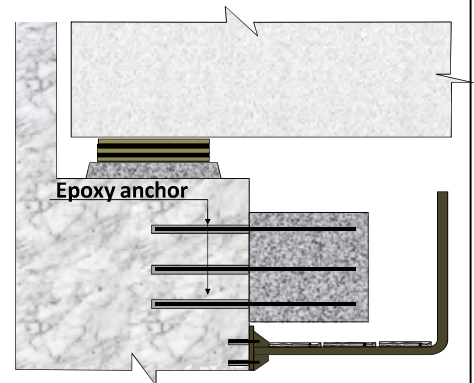
The material test shall be applied for Hardness test to be approved by the Engineer.

#### 5.2 Work requirement

##### (1) Installation of jacking stages

The Contractor shall submit the shop drawings of jack up bracket staging and the working staging to be approved by the Engineer.

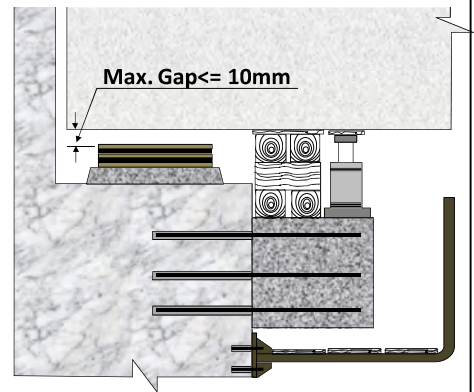
The jack up bracket shall strong enough against reaction from jacking load. Concrete of the bracket shall be cured until concrete strength developed required strength.



##### (2) Jack up girder

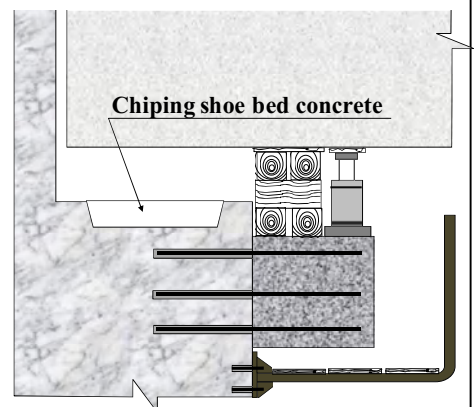
The jack capacity shall be agreed with the Engineer considering dead load and live load during the replacement work.

The surface of expansion joint shall be secured to provide safety for passing traffic during jacking up process. Moreover, the height difference between surface of abutment and girder shall be kept smaller than 10 mm.



##### (3) Casting bearing seat and set up new bearings

The Contractor shall submit shop drawings for the new bearing seat to be approved by the Engineer, prior to execution of related works including concrete chip off. After providing temporary support for the girders near the bearing locations, old bearings shall be dismantled. Position and level for the new bearings shall be set-up accordingly.



## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Difference in Level due to Defect of Bearing**

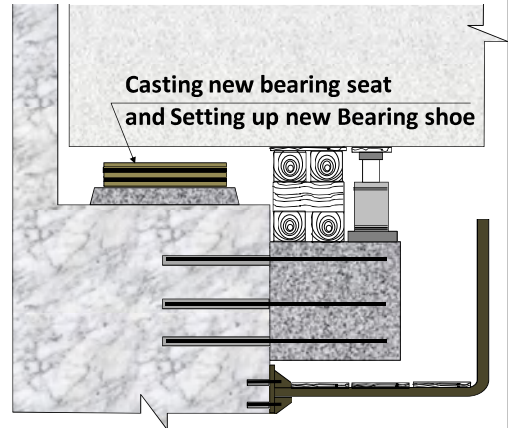
**PLATE 3 - 19**

**Remedial Measure**

**Replacement of Rubber Bearing**

**(4) Jack down girder After Curing**

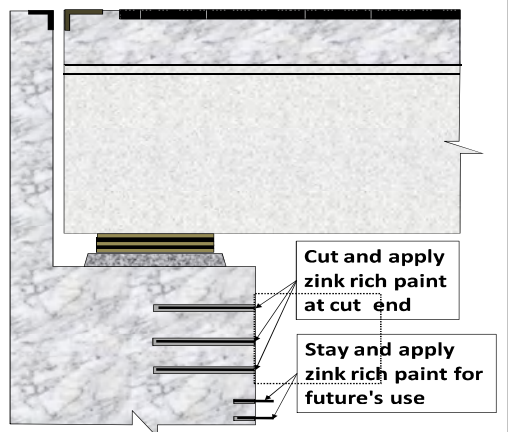
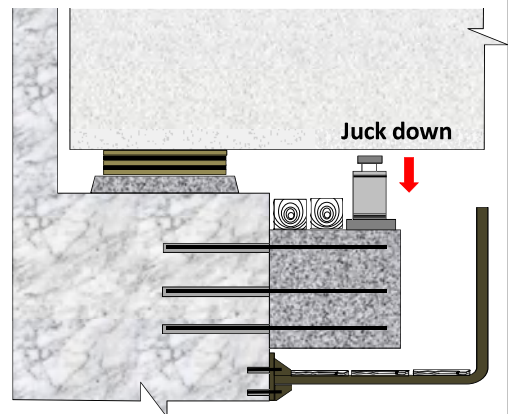
Mortar/concrete shall be cured to achieve sufficient strength for supporting the load reactions. The Contractor shall submit test results of specimen strength in accordance with the specifications, subject to approval of the Engineer. If the test results are acceptable, jack down the girder to consequently release load reactions from the jacking device.



**(5) Dismantle Jacks and Temporary Supports**

When the reaction is safely transferred from the jack to the new bearing, jacking device shall be dismantled.

Temporary jacking bracket and staging shall be removed, epoxy anchors for bracket shall be cut at the surface of the concrete and cut end shall be applied zinc rich paint. Staging anchor bolts shall be remained with application of zinc rich paint for future's use.



### 6. Measurement and Payment

**6.1 Method of Measurement**

The method of measurement for replacement of bearings shall be by number (quantity) approved by the Engineer.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Difference in Level due to Defect of Bearing</b>	<b>PLATE 3 - 19</b>
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<b>Remedial Measure</b>	<b>Replacement of Rubber Bearing</b>
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### 6.2 Basis of Payment

The quantities, measured as prescribed above shall be paid for at the contract unit price which shall cover full compensation for furnishing, preparing, fabricating, transporting, placing and installation. The new rubber bearing, jack up work, chipping concrete, pouring concrete/grout, jack down work and other activities are deemed included in priced item.

Pay Item No.	Name	Unit of Measurement
3-19	Replacement of Rubber bearing shoe	Number

## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Defect of reinforcing material**

**PLATE 3-20**

**Remedial Measure**

**Re-bonding of strengthening plate**

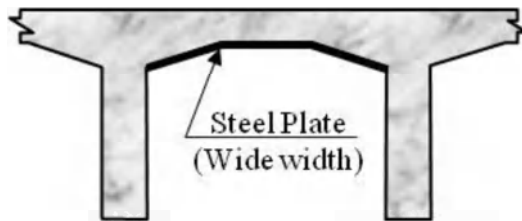
### 1. Work description

The technique of bonding steel plates to concrete deck slab using epoxy adhesives has been used on a number of bridges to enhance their load carrying capacity. The effect of bonding a plate to the tension side of a reinforced concrete section is to increase the depth from the compression side to the neutral axis and the area of effective reinforcement, thus, increasing the moment of resistance of the section.

The steel plate bonding with Wide plates are used often, however the durability of adhesives of plates is limited to 10 years or even shorter for former Injection method with former adhesives. If defect of strengthening steel plate is found widely, the Re-bonding of plates is required.

Figure 3-20-1 Steel Plate Bonding

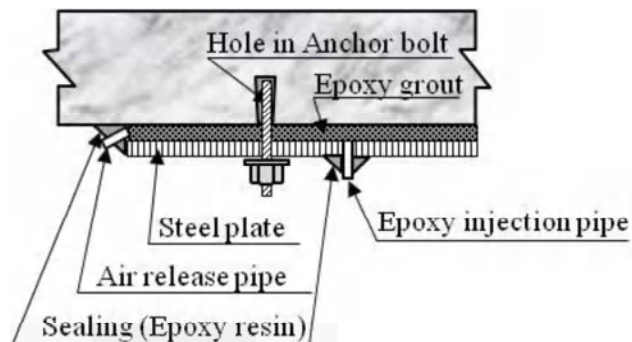
Wide Plate Type (Injection Method)



### 2. Application criteria

Wide Plate Type with Injection Method is usually applied for deck slabs in which rebars in both of directions are damaged. The bonding method of the steel plate is by Injection Method in which the steel plate is bonded to concrete deck slab by injection of Epoxy Resin into space between concrete deck slab and the steel plate set by anchor bolts as shown Figure 3-20-2.

Figure 3-20-2 Steel Plate Bonding -Injection Method)



## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Defect of reinforcing material**

**PLATE 3-20**

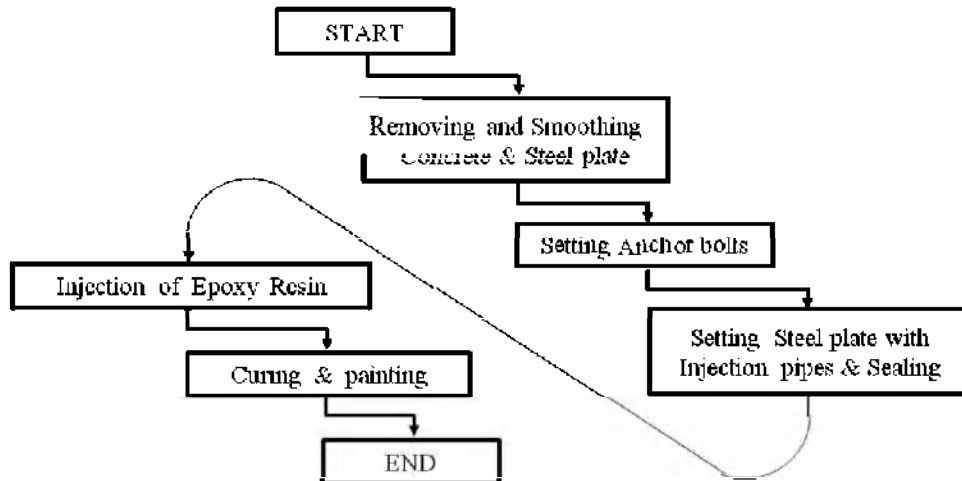
**Remedial Measure**

**Re-bonding of strengthening plate**

### 3. Work sequence

Defect of de-bonding is caused by bad former epoxy grout quality or insufficient injection work. Corrosion of steel plates is another damage type. If the de-bonding is found partly, partly Injection method is chosen. By large defect is chosen, totally removing plates, and then full re-bonding is recommended. Work sequence of Re-bonding of strengthening plate Method is as shown in Figure 3-20-3.

Figure 3-20-3 Work sequence of Re-Bonding-Injection Method



### 4. Required Equipment/Tools and Material

#### 1) Equipment/Tools

The following Equipment/Tools will be necessary for Steel Plate Bonding-Injection Method works:

- Disc Grinder
- Welder
- Electric Drill
- Epoxy Injection Pump with Accessories
- Wire Brush

#### 2) Materials

The following materials will be necessary for Steel Plate Bonding-Injection Method works:

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Defect of reinforcing material</b>	<b>PLATE 3-20</b>
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<b>Remedial Measure</b>	<b>Re-bonding of strengthening plate</b>
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- Steel Plate
- Primer (Epoxy Base)
- Epoxy Resin Adhesive for Injection
- Epoxy Sealant
- Anchor Bolts (Hole in type)

### 5. Requirement, Specifications

#### 5-1 Material

The Materials shall be approved by the Engineer through mill certificate of the supplier.

1) Steel Plate

Steel Plate is in accordance with ASTM A36.

2) Epoxy Grout

Epoxy Grout (Epoxy Resin Adhesive) shall conform to the requirements of the specifications shown in Table 3-20-2, or equivalent ASTM Specifications.

Table 3-20-2 Specification of Epoxy Grout

Property	Test Method	Unit	Specification
Specific Gravity	ASTM D792M	-	3-2 ± 0.2
Viscosity	ASTM D2393	mPa · s	5000 below
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	40 /above
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	50 /above
Compressive Young's Modulus	ASTM D695M	N/mm <sup>2</sup>	1500 /above
Tensile Strength	ASTM D638M	N/mm <sup>2</sup>	20 /above
Slant Bond Strength to Concrete	ASTM C882	N/mm <sup>2</sup>	15 /above
Tensile Shear Bond to Steel	ASTM D1002	N/mm <sup>2</sup>	15 /above

3) Epoxy Sealant

Epoxy Sealant shall conform to the requirements of the specifications shown in Table 3-20-3, or equivalent ASTM Specifications.

## MAJOR REPAIR METHODS

<b>Defect/Deficiency</b>	<b>Defect of reinforcing material</b>	<b>PLATE 3-20</b>
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<b>Remedial Measure</b>	<b>Re-bonding of strengthening plate</b>
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Table 3-20-3 Specification of Epoxy Sealant

Property	Test Method	Unit	Specification
Specific Gravity	ASTM D792	-	1.50 ± 0.3
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	40 above
Compressive Yield Strength	ASTM D695M	N/mm <sup>2</sup>	50 above
Tensile Strength	ASTM D638M	N/mm <sup>2</sup>	30 above
Tensile Shear Bond Strength	ASTM D1002	N/mm <sup>2</sup>	10 above
Slant Shear Bond to Concrete	ASTM C882	N/mm <sup>2</sup>	15/above

### 5-2 Work requirement

The Contractor shall submit the Methodology Statement of the Work to the Engineer for his review and approval before commencement of the work.

#### 1) Surface preparation

The concrete surface of an existing member will usually be contaminated and have out-of-plane, imperfections and will therefore require preparation before plates are bonded to it. Cracks wider than 0.2 mm which could reduce adhesion and areas of concrete that appear porous should be sealed with a compatible resin.



The surface of the steel to be bonded must be completely free of any mill scale, rust, grease or other contaminants. For successful adhesion of the resin, the contact surfaces of the steel plates should be degreased and blast cleaned at the fabricator's premises. The primer, for the epoxy resin adhesive, should be an epoxy-based system compatible with the adhesive.

#### 2) Setting Anchor bolts

Anchor bolts are required to temporarily support steel plates in the event of setting on the deck slab with an average gap of 5mm between the slab surface and steel plate. The bolt spacing should be sufficient to prevent deflection of the bonded plate



## MAJOR REPAIR METHODS

**Defect/Deficiency**

**Defect of reinforcing material**

**PLATE 3-20**

**Remedial Measure**

**Re-bonding of strengthening plate**

within the defined space.

3) Setting Steel Plate

Injection pipes are attached to the steel plate. Joints between steel plates are welded at site. Minimum plate thickness should not be less than 4 mm in order to avoid distortions during grit blasting and handling on site. Concrete structures to which plates are to be bonded shall be invariably smoothed and surface burnished using a disc grinder.



4) Sealing

The periphery of the steel plate shall be sealed with epoxy putty as well as the area surrounding injection holes



5) Injection Epoxy Grout

Procedure trials should always be carried out to confirm the quality of the method of application and acquaint the applicators with the materials to be used. Where epoxy grout is to be injected, the mixing continuously takes place during injection. The epoxy grout shall be injected through injection pipes, gradually withdrawn as filling takes place.



The manufacturer's instructions on safe use of resins should be followed.

6) Curing and Painting

To protect the adhesive against moisture ingress, the edges of the plate should be sealed with resin putty or mortar after the adhesive has cured. A suitable chamfer/fillet



**MAJOR REPAIR METHODS**

<b>Defect/Deficiency</b>	<b>Defect of reinforcing material</b>	<b>PLATE 3-20</b>
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<b>Remedial Measure</b>	<b>Re-bonding of strengthening plate</b>
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could also be formed in the adhesive around the edge of the plates and the concrete surfaces. Steel plates and all associated components should be adequately painted for corrosion protection.

**6. Measurement, Payment**

**6-1 Method of Measurement**

Re-bonding of strengthening plate method performed in accordance with the plans and this specification will be measured in square meters. The quantity to be paid for includes the steel plate bonded on the deck slab in square meters, accepted by the Engineer. No measurement will be made for epoxy injection of cracks, if required.

**6-2 Basis of Payment**

The quantity measured as prescribed above, shall be paid for at the contract unit price. Epoxy injection of cracks will not be paid for directly and is considered subsidiary to the works.

This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related services necessary for reinforcing the deck slab by steel plate, as detailed in the plans and specifications.

Pay Item No.	Name	Unit of Measurement
3-20	Re-bonding of strengthening plate	Square Meter (m <sup>2</sup> )







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