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

Part 1. Rehabilitation/Strengthening Method

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Plate list for Major Repair Works

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20	Defect of reinforcing material	Concrete deck slab	Rebonding of strengthening plate	Plate 3-20

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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.

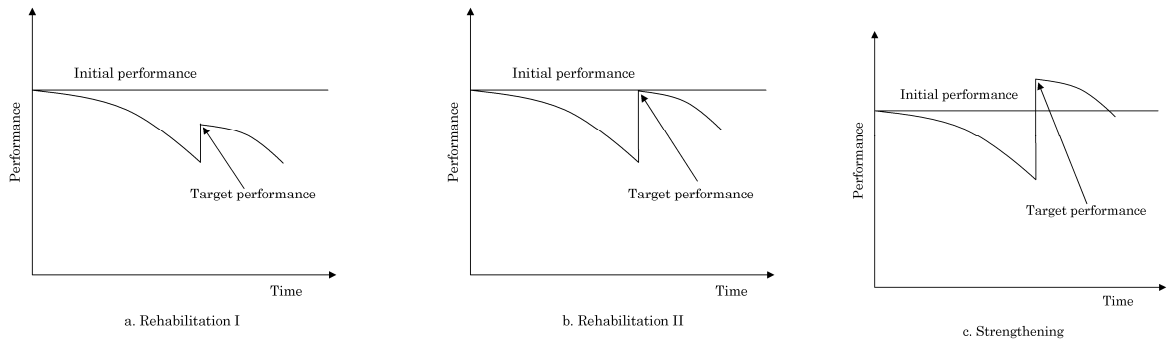


Figure 1-1 Concept of Rehabilitation and Strengthening

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.

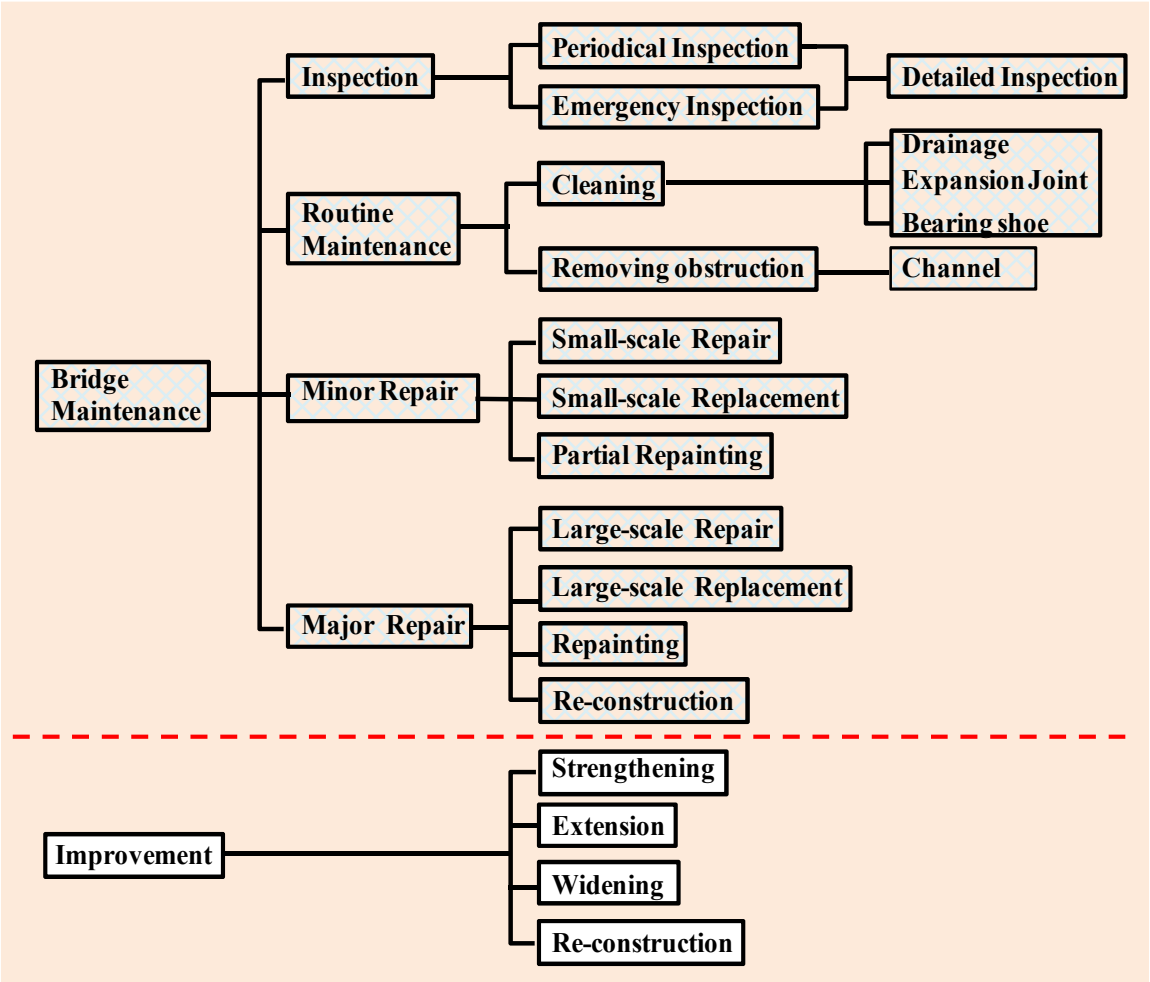
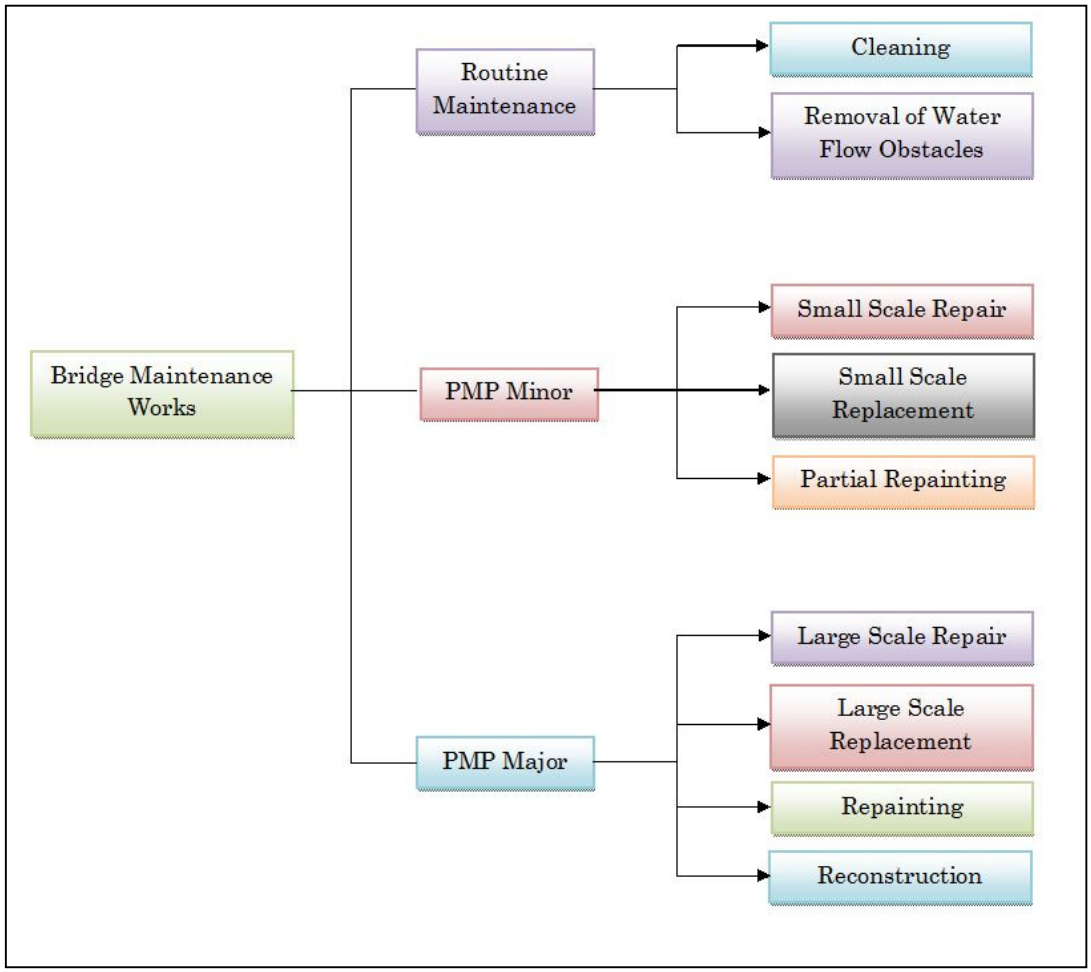


Figure 1-2 Categories of Bridge Maintenance Work

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

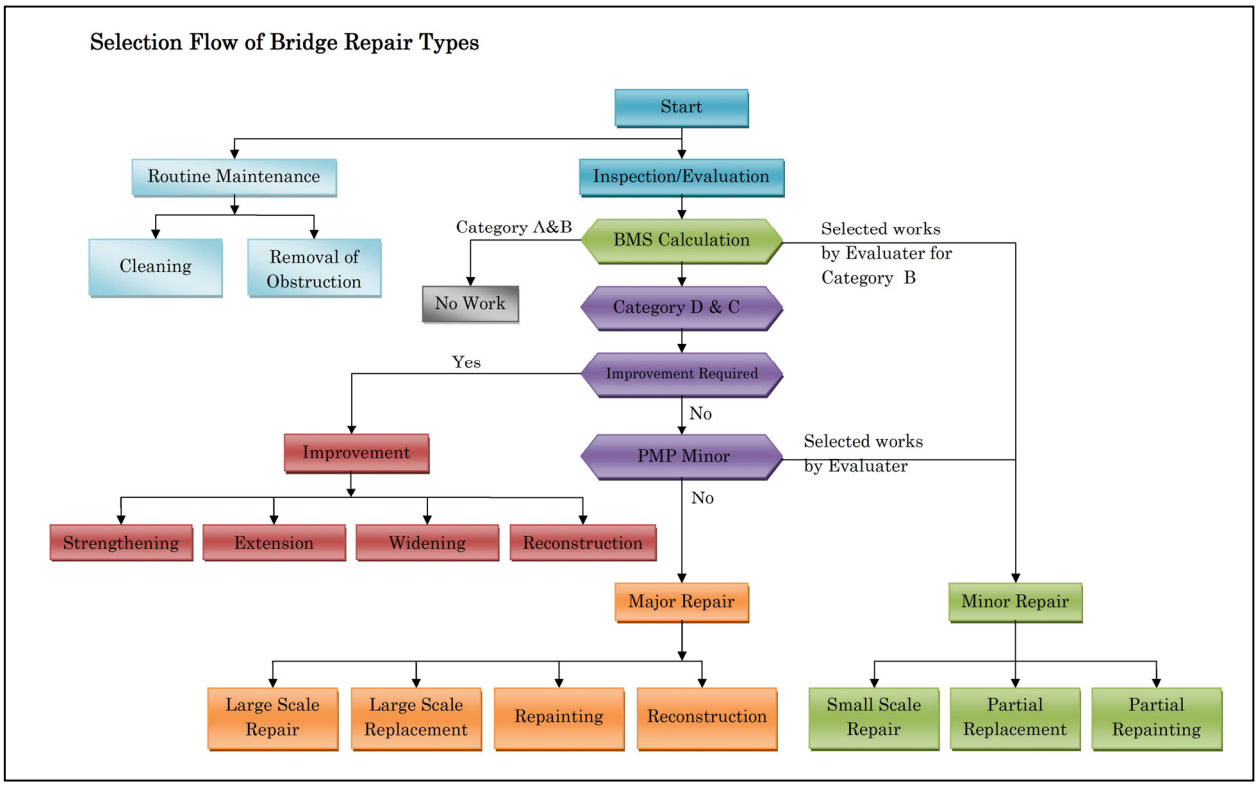
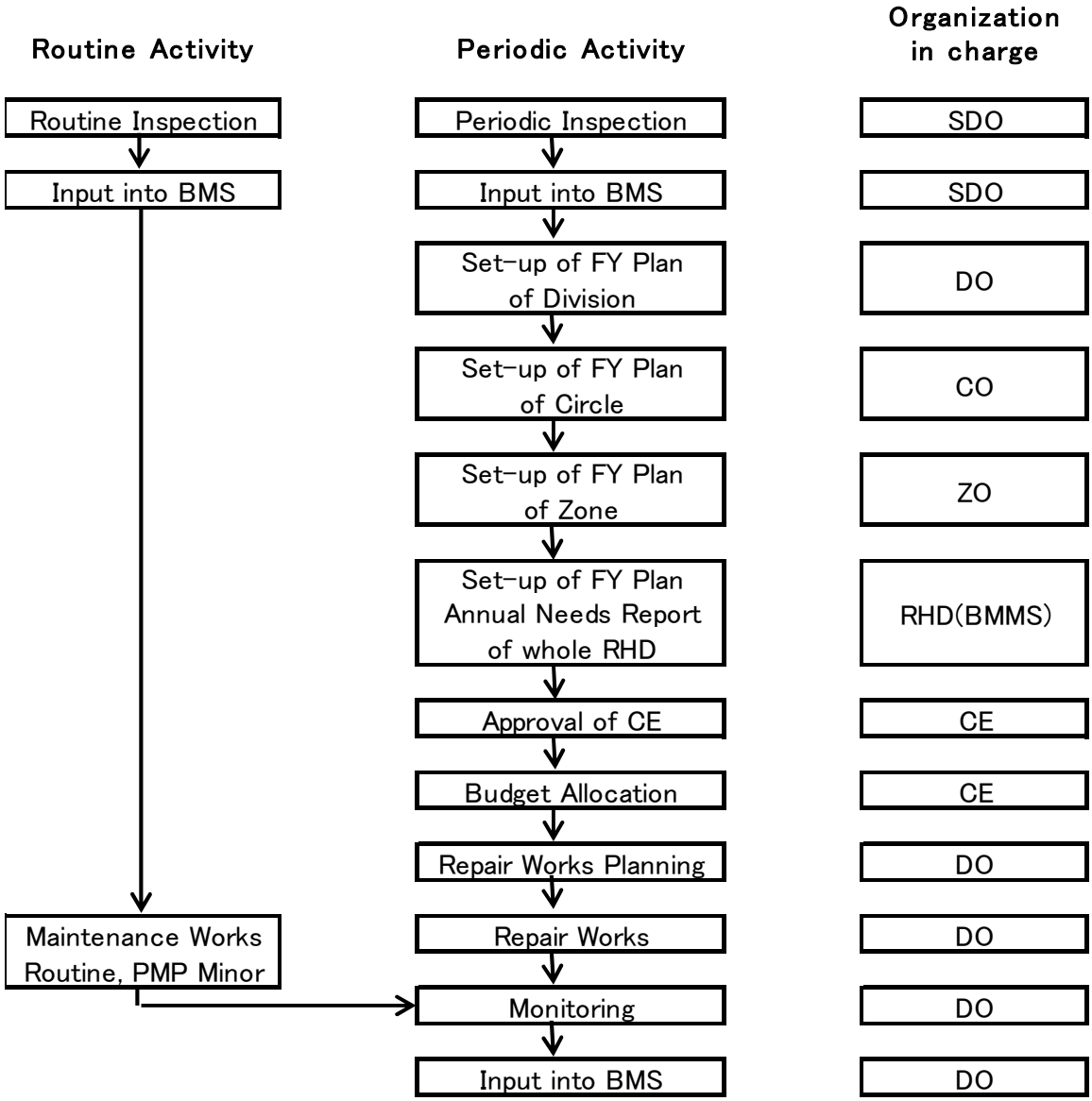


Figure 1-4 Selection Flow of Bridge repair types

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 Roots 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

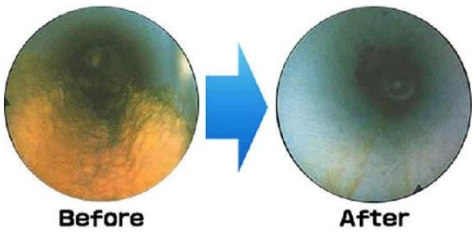


Fig.2-6 Pipe after jet water cleaning

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	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.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	

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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

Plate name	Defect/Deficiency	Remedial Measure
Routine Maintenance Methods		
Plate 1-1	Debris accumulation	Cleaning
Plate 1-2	Water flow obstruction	Removing obstructions
Minor Repair Methods		
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 out-sourced 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)

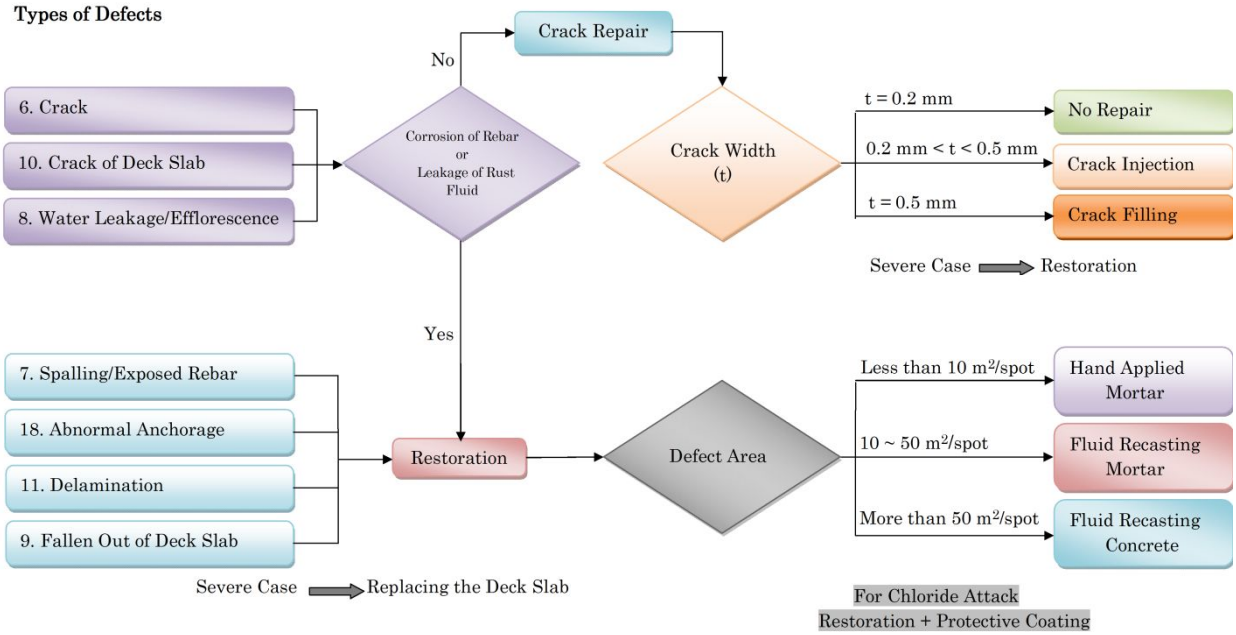


Figure 4-1 Selection Flow of Repair method of Concrete elements (Superstructure)

The Flow based by Local Government Jp

Selection Flow of Repair Method of Concrete Elements (Substructure)

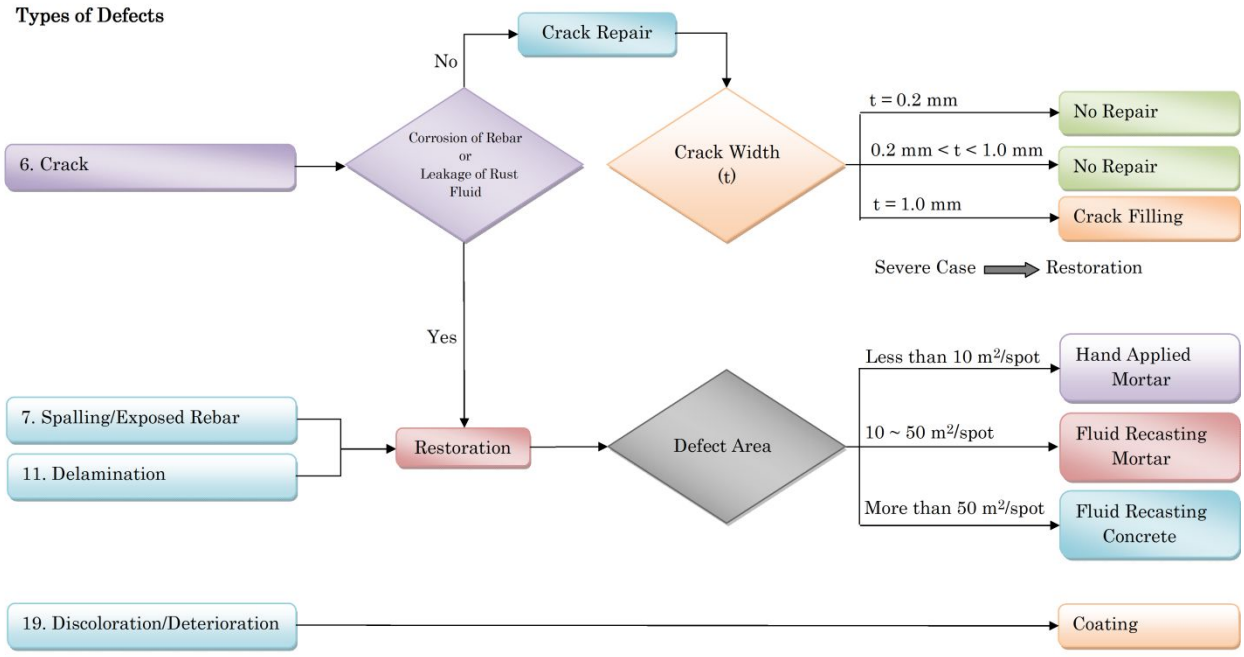


Figure 4-2 Selection Flow of Repair method of Concrete elements (Substructure)

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.

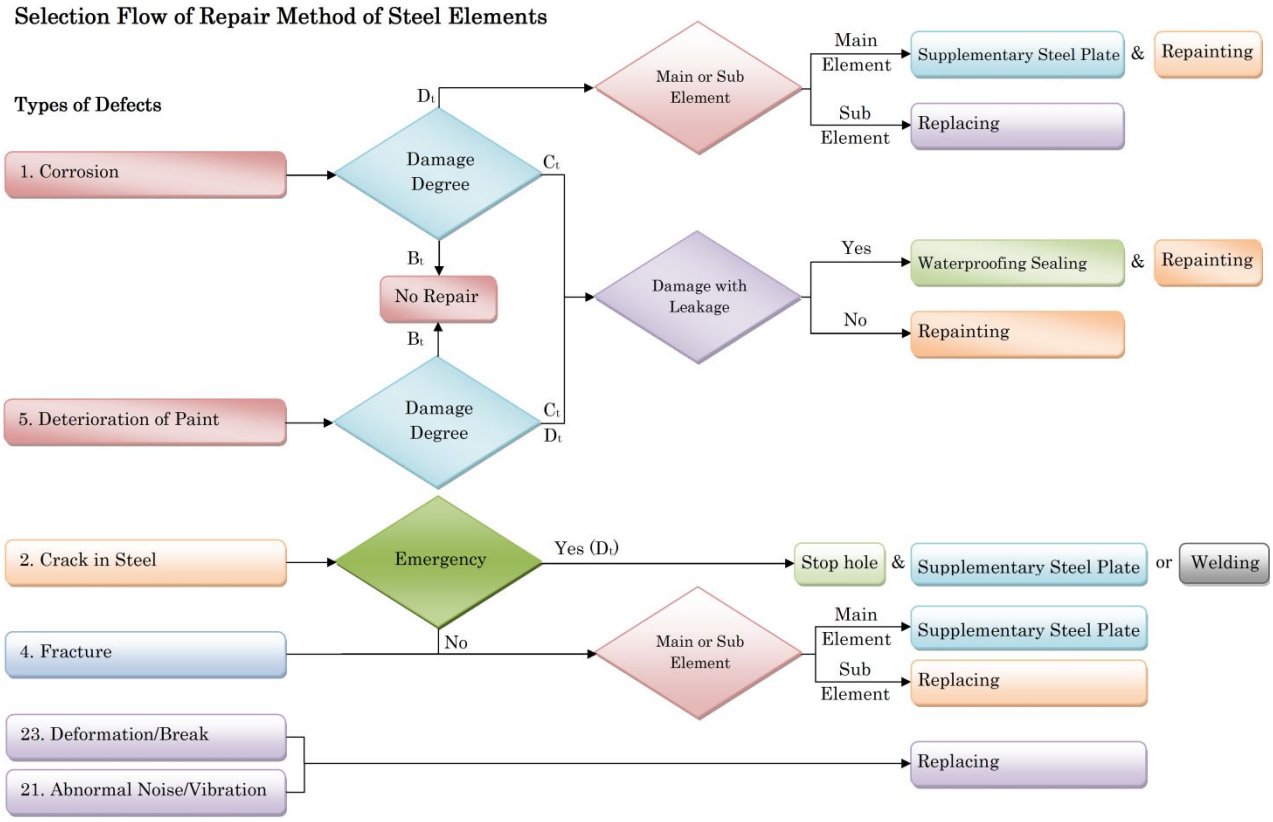


Figure 4-3 Selection Flow of Repair method of steel elements

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).

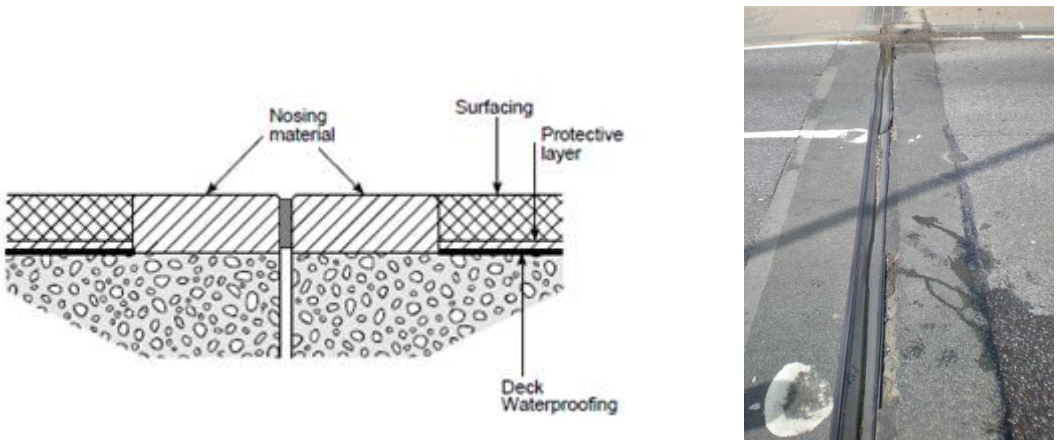


Figure 4-4 Nosing joint with poured seal (left) and its surface damage (right)

The usual gap of concrete edge is around 20 mm considering temperature here in Bangladesh as 41℃~7℃ (=24℃±17℃). The thermal movement of the concrete bridge span is;

Δ temp = α ・L・ δ T

= 12×10^{-6}/℃×20 m×(±17℃) = ±4.1 mm for L; 20 m ; Concrete girder

= 12×10^{-6}/℃×30 m×(±17℃) = ±6.1 mm for L; 30 m

= 12×10^{-6}/℃×40 m×(±17℃) = ±8.2 mm for L; 40 m

And for steel bridges, the thermal movement is; 51℃~7℃ (=29℃±22℃)

Δ temp = α ・L・ δ T

= 12×10^{-6}/℃×20 m×(±22℃) = ±5.3 mm for L; 20 m ; Steel girder

= 12×10^{-6}/℃×30 m×(±22℃) = ±7.9 mm for L; 30 m

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.

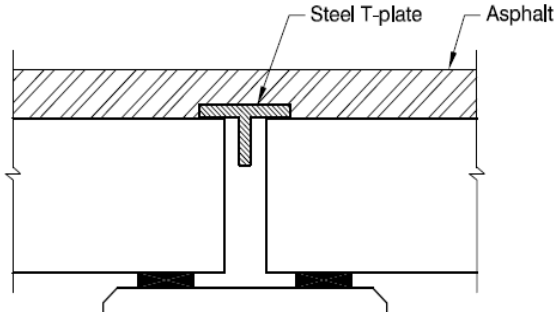


Figure 4-5 Buried joint with steel T-plate

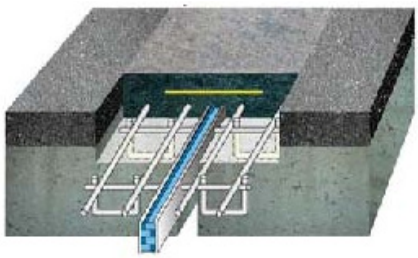


Figure 4-6 Asphaltic plug joint (left) and its surface damage (right)

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.

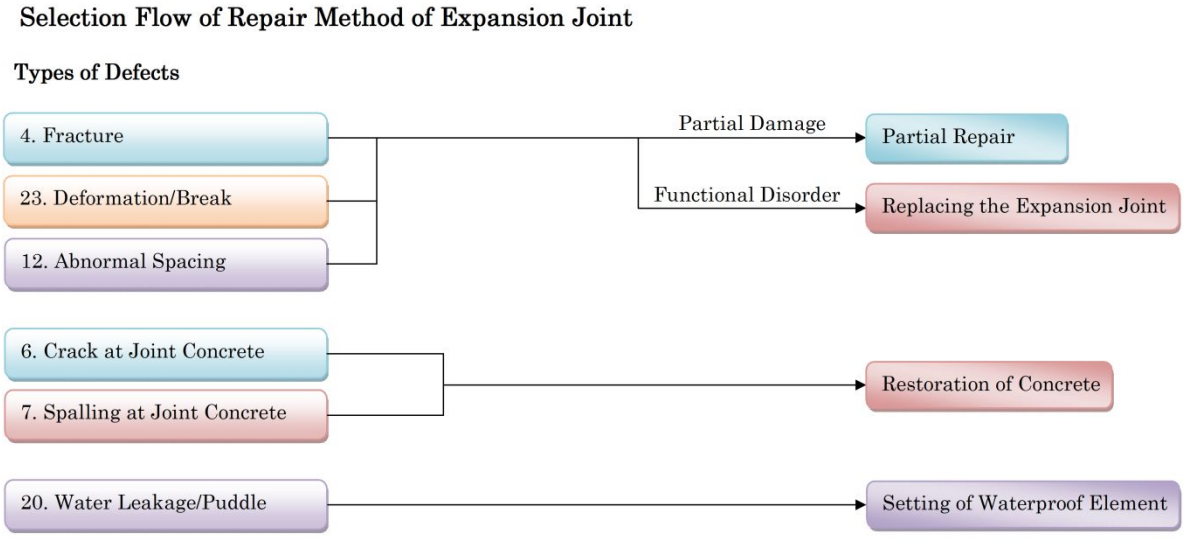


Figure 4-9 Selection Flow of Repair method of Expansion joint

The Flow based by Local Government Jp

"**Consideration on the thermal movement of Bridges**"

AASHTO (WSDOT 2015)

Temperature Range 38℃~ -20℃ (=9℃±29℃) for concrete

49℃~ -20℃ (=14.5℃±35℃) for steel

Japan (JRA 2013)

Temperature Range 35℃~ -5℃ (=15℃±20℃) for concrete

40℃~ -10℃ (=15℃±25℃) for steel

Bangladesh (Bridge Maintenance Manual 2014)

Temperature Range 35℃~7℃ (=21℃±14℃) for concrete

none for steel

BD Bridge Maintenance Manual 2017 (assumed)

Temperature Range 41℃~7℃ (=24℃±17℃) for concrete

51℃~7℃ (=29℃±22℃) for steel

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

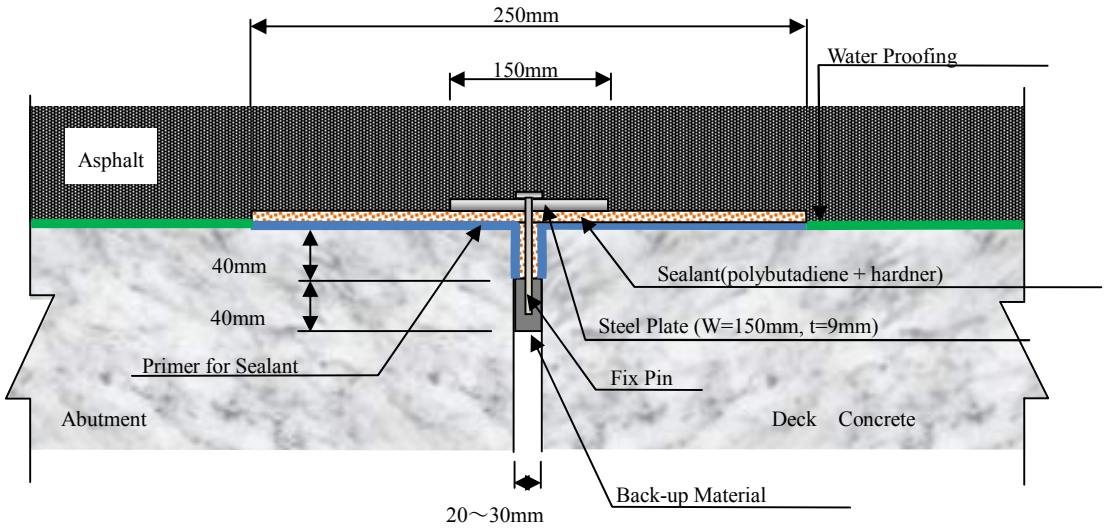


Figure 4-10 modified Buried joint with steel T-plate

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.

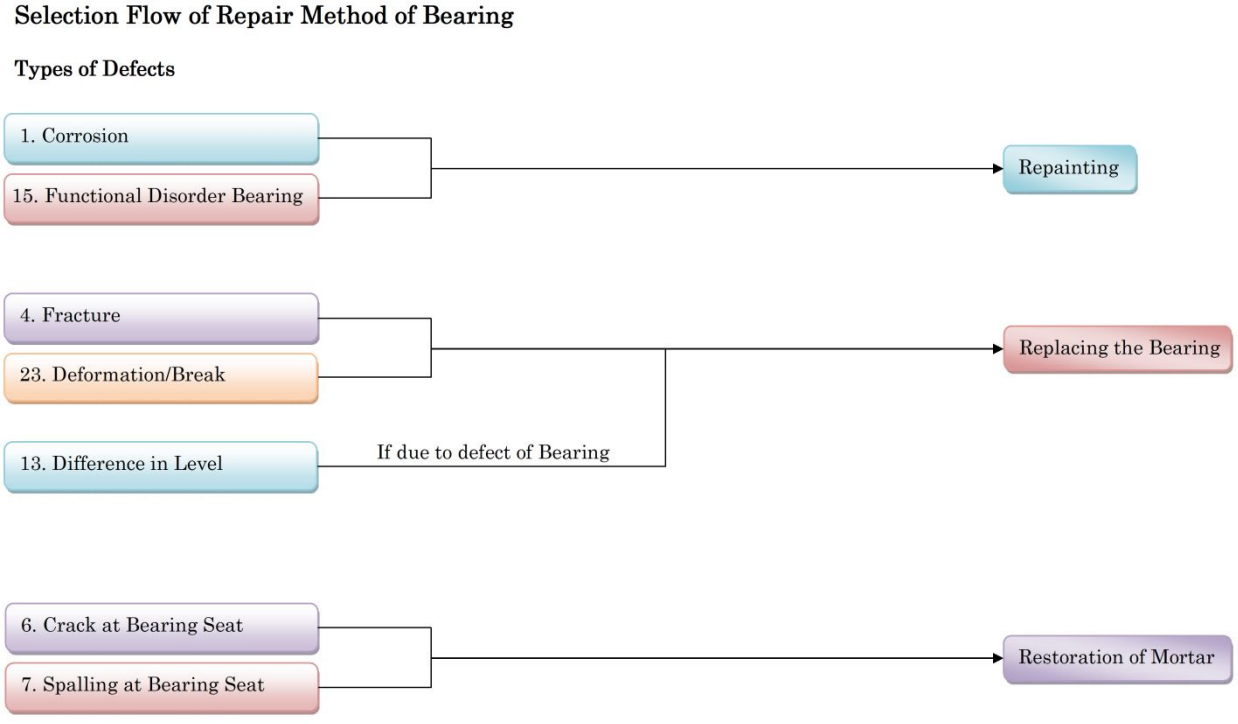


Figure 4-11 Selection Flow of Repair method of Bearing

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.

Figure 4-12 Scour repair work by special heavy equipment

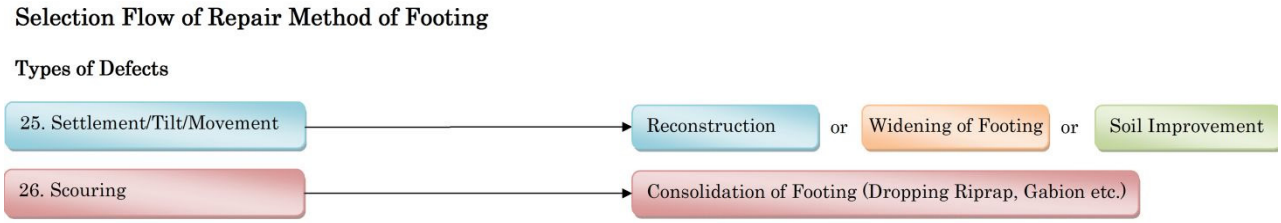


Figure 4-13 Selection Flow of Repair method of Footing

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).

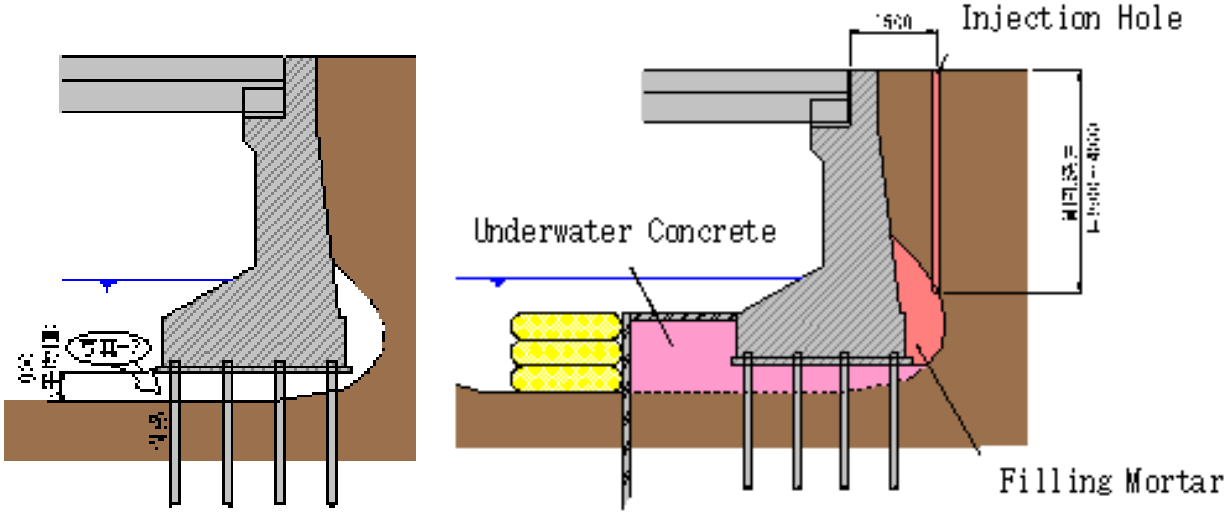


Figure 4-15 Scour repair work with Underwater concrete and mortar

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 Repalcement 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
Routine Maintenance Methods			
Plate 1-1	Debris accumulation	Cleaning	
Plate 1-2	Water flow obstruction	Removing obstructions	
Minor Repair Methods			
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	

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

1. Work description

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.

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.

Photo 1-1-1 Cleaning of Bearing by jet water

Photo 1-1-2 Cleaning using Inspection Vehicle

2. Application criteria

Criteria for cleaning applied to the bridge including its steel surface, deck and substructure are recommended below:

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

1) Surface of steel plate

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.

Washing of steel bridges should be carried out in the flowing Zones expedi:tiously;

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.

2) Bridge deck slab:

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.

3) Bridge substructure:

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.

4) Vegetation growth

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.

A few typical examples of debris accumulation have been illustrated following;

Photo 1-1-3 Vegetation in deck / girder

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

Photo 1-1-4 Joint clogged with sand and dust

Photo 1-1-5 Ponding on deck

Photo 1-1-6 Debris on bearing

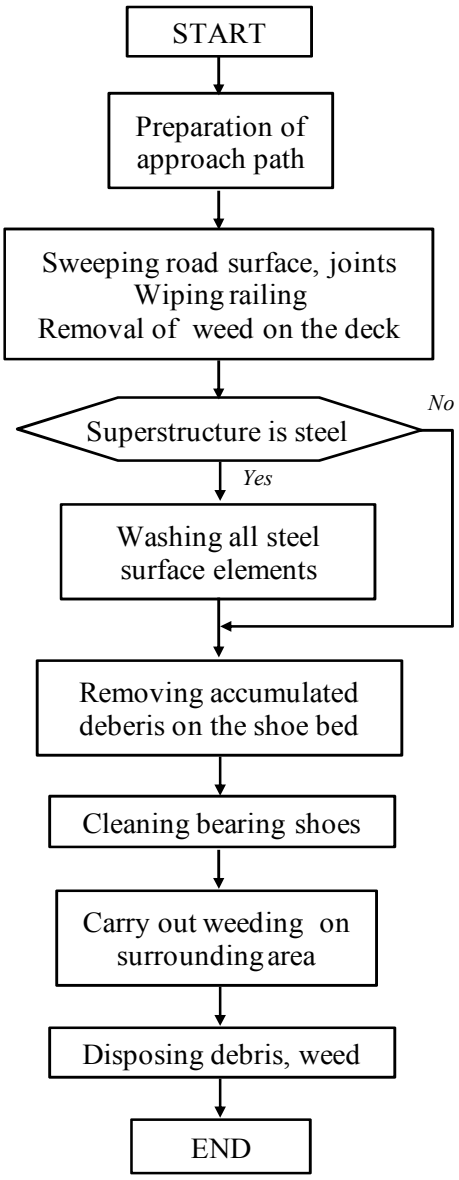
Photo 1-1-7 Vegetation on substructure

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

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

5. Requirement, Specification

5.1 Material Requirement

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.

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.

5.2 Work Requirement

1) General

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.

2) High pressure water

Salt contaminants, dirt, and other detrimental foreign matters shall be removed without damaging or peeling the paint from any structural steel. If high-pressure water is used, the maximum water pressure shall not be so high that any paint is damaged. The cleaning operation shall be discontinued if the foreign materials have not been easily removed or if cleaning operation is causing damage to existing paint coating. In this situation, the high-pressure water shall be adjusted to clean the surface without damaging the paint coating.

All deck drains and its accessories shall be flushed with high-pressure water after the accumulated foreign material has been properly removed. Drain systems may have to be disassembled to remove large blockages of accumulated foreign material. Should this be necessary, these shall be returned to their original configuration immediately after cleaning. Drainage systems shall drain properly after cleaning.

The Contractor shall flush out the interior surfaces of all girders and truss members

using high-pressure water. This flushing shall continue until such time that clear water is being draining out. The exterior surfaces of all truss members, miscellaneous structural steel connecting the truss members, and floor beam ends projecting outwardly from the row of exterior stringers shall be thoroughly washed down using high-pressure water.

The Contractor shall obtain approval of the source of water used. They shall use fresh water which is free of sediments and salt contaminants and be responsible for all expenses involved in securing the approved water.

6. Measurement and Payment

6.1 Method of Measurement:

Bridge cleaning shall be taken as a lump sum item.

6.2 Basis of Payment:

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.

Pay Item No.	Name	Unit of Measurement
1-1	Cleaning	Lump sum (L/P)

ROUTINE MAINTENANCE METHODS		
Defect/Deficiency	**Water flow obstruction**	**PLATE 1-2**
Remedial Measure	**Removing obstructions**	

1. Work description

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.

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.

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.

2. Application criteria

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.

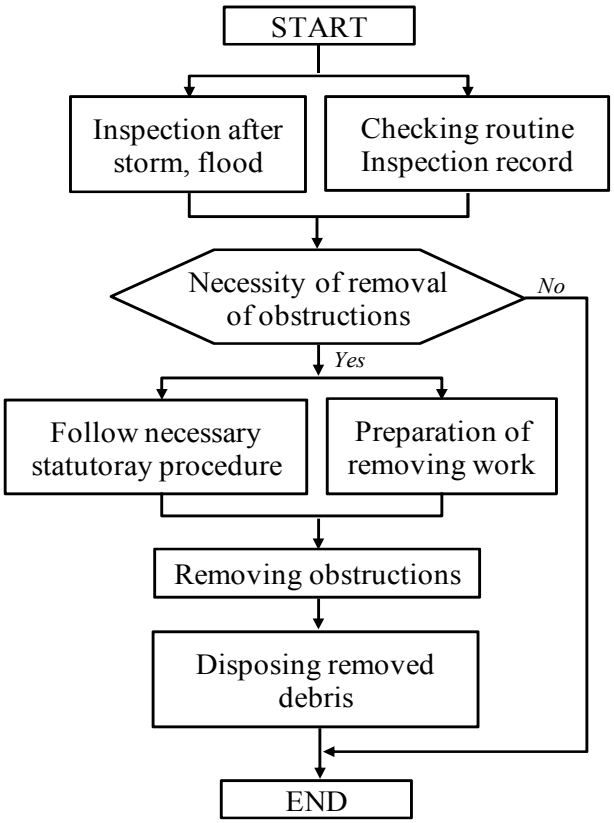
Photo 1-2-1 Driftwoods and debris around the piers

ROUTINE MAINTENANCE METHODS		
Defect/Deficiency	**Water flow obstruction**	**PLATE 1-2**
Remedial Measure	**Removing obstructions**	

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

ROUTINE MAINTENANCE METHODS		
Defect/Deficiency	**Water flow obstruction**	**PLATE 1-2**
Remedial Measure	**Removing obstructions**	

5. Requirement, Specification

5.1 Work requirement

1) Inspection and Checking of the Routine inspection record

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.

2) Preparation

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.

3) Statutory procedure

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.

4) Removing obstructions

Floating debris, driftwoods etc. shall be removed and disposed properly to a designated place. It may be necessary to cut the large driftwoods into pieces for disposal.

Burning of the removed materials within the right of way is not permitted. The disposed material should be stockpiled at a designated area and dried. The contractor shall address all environmental issues associated with removal and disposal of debris from bridge sites.

6. Measurement and Payment

6.1 Method of Measurement

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

6.2 Basis of Payment

ROUTINE MAINTENANCE METHODS		
Defect/Deficiency	**Water flow obstruction**	**PLATE 1-2**
Remedial Measure	**Removing obstructions**	

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.

Pay Item No.	Name	Unit of Measurement
1-2	Removing obstructions	lump sum (L/P)

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

1. Work description

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

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.

2. Application criteria

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.

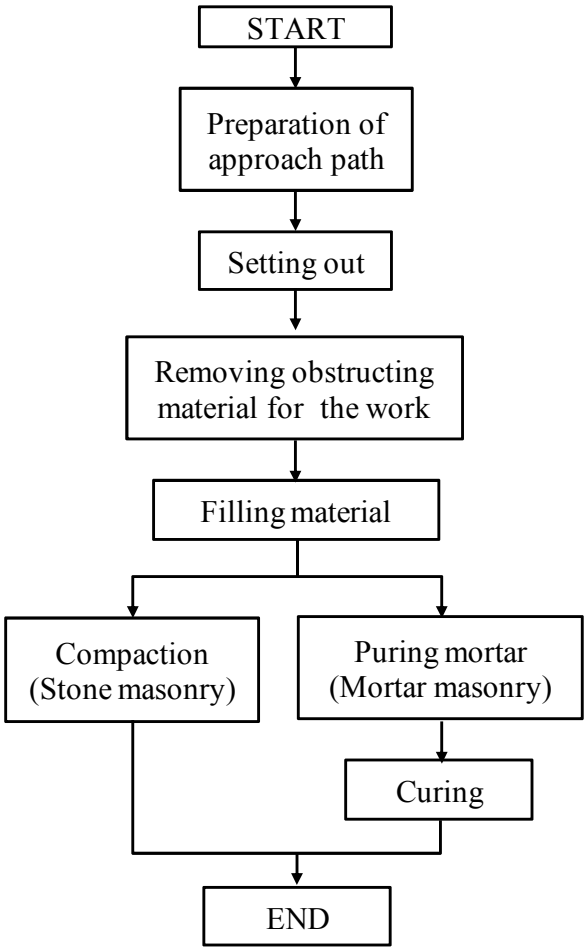
Photo2-1: Missing stone in existing masonry work

3. Work sequence

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

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

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

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.

5) Curing

After laying of the bricks / stones into the existing mortared masonry work, curing with water shall be done after the initial setting of the mortar at the joints, and shall be continuously cured for 7 days.

6. Measurement and Payment

6.1 Method of Measurement

These works will be measured by cubic meter or by lump sum for sites described on the plans.

6.2 Basis of Payment

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.

Pay Item No.	Name	Unit of Measurement
2-1-(1)	Repairing Stone masonry (1)	Cubic meter (m^3)
2-1-(2)	Repairing Stone masonry (2)	Lump sum (L/P)
2-1-(3)	Repairing Mortar masonry (1)	Cubic meter (m^3)
2-1-(4)	Repairing Mortar masonry (2)	Lump sum (L/P)

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

1. Work description

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.

The work herein comprises restoration of the gabion works by replacing the damaged wires.

2. Application criteria

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.

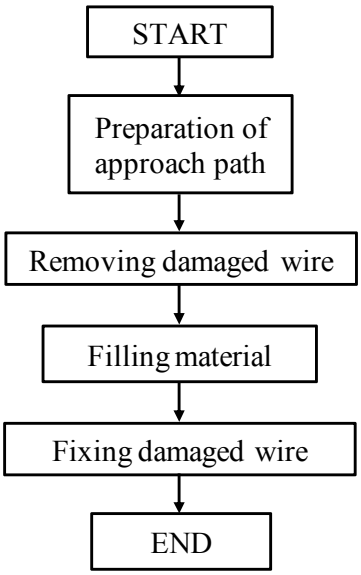
Photo-2-2: Deterioration in gabion wire mesh

3. Work sequence

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

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

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

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

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) 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.

4) Fixing wire mesh

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.

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

6. Measurement and Payment

(1) Method of Measurement

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

(2) Basis of Payment

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.

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^2)

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

1. Work description

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.

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.

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.

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.

Photo 2-3-1 Spalling Concrete

2. Application criteria

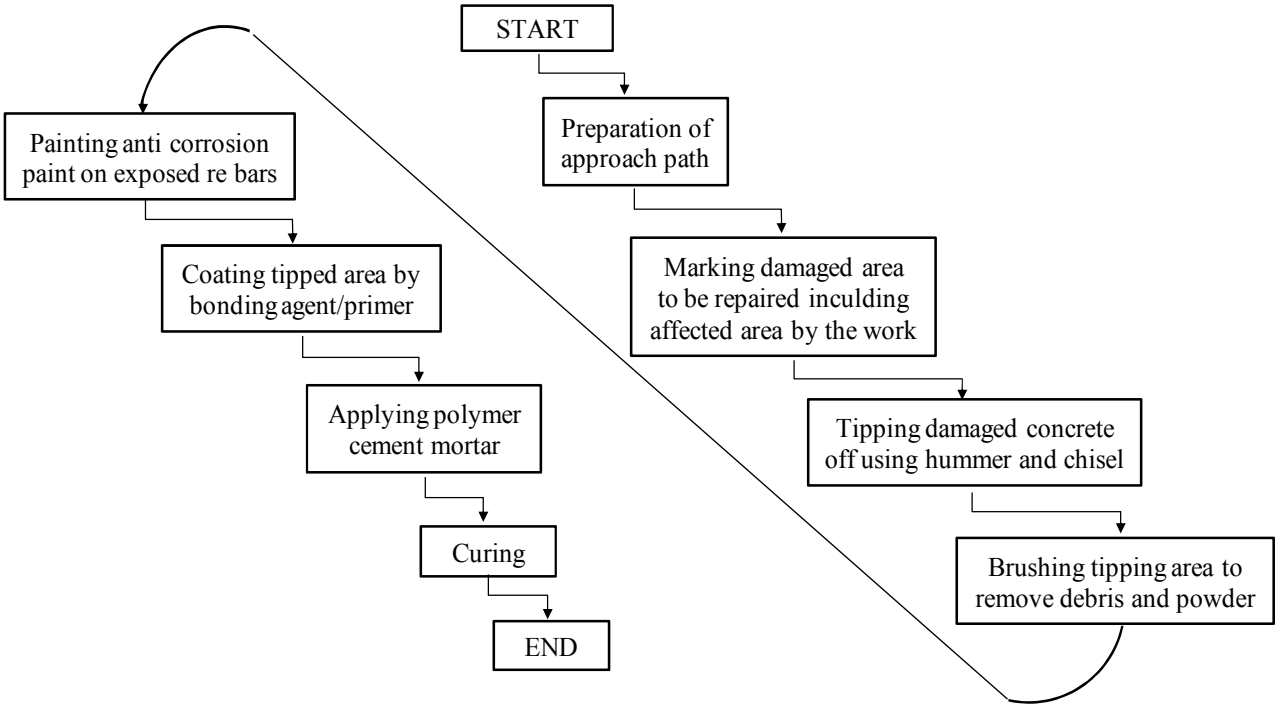
Spalling of width less than 300 mm and depth less than 50mm have been dealt with here. The repair comprises application of polymer cement repair mortar on the spalled portion of concrete after treating the area with suitable bonding agent and after applying anticorrosion paint on the surfaces of the corroded rebar, if any. The work requires adequate curing.

3. Work sequence

Work sequence of Epoxy Coating is as shown Figure 2-3-1.

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		
Defect/Deficiency	**Spalling, Minor honey comb**	**PLATE 2-3**
Remedial Measure	**Patching**	

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	2.0×10^{-5} mm/mm/^{o}C
Slant shear bond to concrete	ASTM C882	Concrete failure above 15 N/mm^2
Compressive strength	ASTM D695M	above 20 N/mm^2

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^2
Flexural strength	ASTM D790M	40 N/mm^2
Tensile strength	ASTM D638M	30 N/mm^2
Tensile shear bond to steel	ASTM 1002	15 N/mm^2
Slant shear bond to mortar	ASTM C882	15 N/mm^2
Bond Strength of Cured Concrete to Fresh Concrete	ASTM D7274	15 N/mm^2

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±2

5.2 Work requirement

1) General

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

provisions of relevant standards and manufacturer's specifications. Patching, as a minor 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:

2) Marking of patching area

Evaluate surface area to be patched using hammer for hollow sounding delaminated area (or by using instruments to detect unsound concrete).

Mark the area to be patch-repaired with paint or marker. Ensure complete coverage of the damage.

3) Tipping damaged concrete off

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.

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.

Patch areas that are within 600 mm of each other should be combined into a single large patch.

If necessary, provide formwork around the damaged concrete to straighten the edges of the damaged section.

4) Coating tipping area

Concrete surfaces to receive repair mortar shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss. The clean and dust free surface shall then be coated by a bonding primer.

Care shall be taken to ensure that vibration associated with the repair works does not cause delamination of existing adjacent plaster or concrete.

5) Applying bonding agent and anti corrosion paint

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.

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

If rebar is exposed, anticorrosion coating should be applied on the bar surface prior to patching.

6) Patching mortal

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.

7) Finishing

As may be required, the mortar surface can be smoothened 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.

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.

8) Curing

All types of concrete repair with repair mortar need thorough and continuous curing to develop strength and impermeability. Curing also minimizes drying shrinkage while bond strength is developing. Curing of the repair mortar shall be in accordance with the manufacturer's instructions related to the polymer modified additive. Where curing agents are specified by the manufacturer, they shall be applied immediately after the surfaces have been scarified for the next repair mortar layer, or troweled to a finish.

6. Measurement and Payment

6.1 Measurement

Area prepared for patching shall be measured in square meter after removal of concrete of

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

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

Pay Item No.	Name	Unit of Measurement
2-3	Patching	Square Meter (m^2)

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

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.

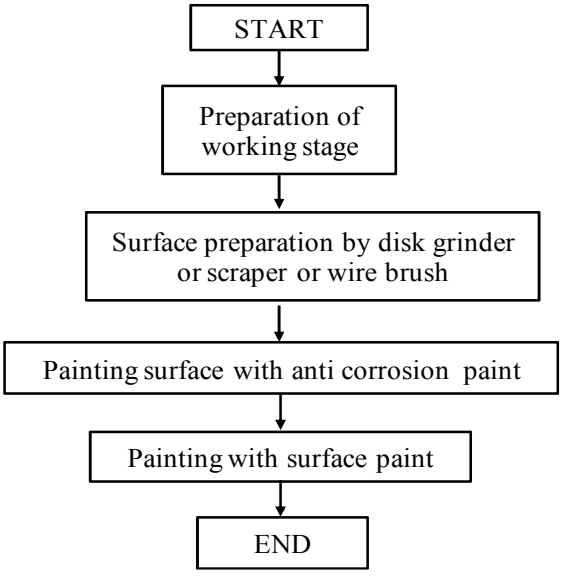
Where condition of paint is evaluated as Grade-2 (affected surface 20-30%) with loss of section within 20%, special anticorrosion paint shall be applied to restrict corrosion from progressing further.

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

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^2, 28days 1.5 N/mm^2
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.

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

2) Preparation of Steel Surface:

Surface preparation shall conform to the paint manufacturer's specifications. Hand or power tools shall be applied for cleaning the surface

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.

Application of aluminum paint material shall be in accordance with the manufacturer's specifications and as approved by the Engineer.

3) Application of Touchup Paint

Paint shall be applied with brush or roller. The paint shall be applied in such a way that a uniform and smooth surface is formed without wrinkles, runs, streaks, sags, or any other defects. Components of the paint shall be mixed in accordance with the manufacturer's instructions and the application shall also conform to such instructions and specifications. Paint shall be applied immediately after the surface preparation, preferably within 4 hours.

Total dry film thickness for special anticorrosive paint shall be 500μm (equivalent 1.5kg/m^2) consisting of two layers of coating as follows:

- Layer-1: 250μm
- Layer-2: 250μm

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 μm.

Roval paint is recommended for galvanized member touchup painting.

Total dry film thickness for Roval paint shall be 80μm (equivalent 0.5kg/m^2) consisting of two layers of coating as follows:

- Layer-1: 40μm
- Layer-2: 40μm

Roval paint shall be applied in accordance with the stipulations of paint manufacturer's specifications.

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^2)

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

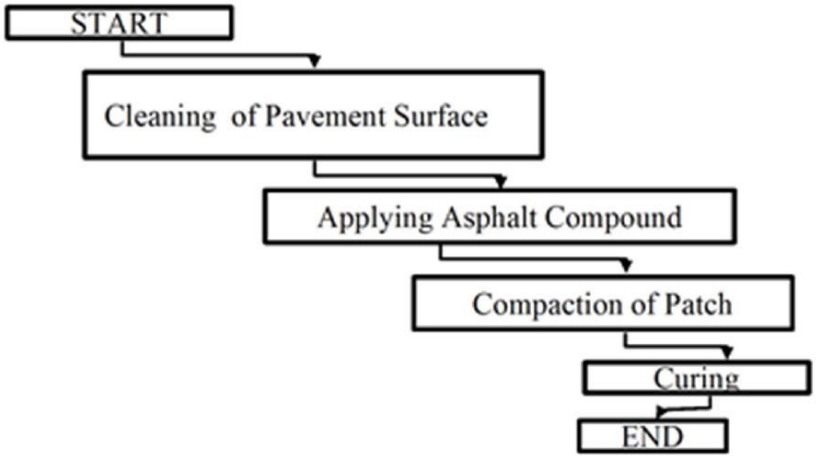


Photo5-2 Surface Cleaning

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

Property	Test Method	Unit	Specification
Penetration with Conic Needle	ASTM D217	mm	2 ~ 5
Melting Temperature	ASTM D3461	^{o}C	80
Elongation	ASTM D 638	%	3.5
Tensile Strength	ASTM D 638	Kgf/cm^2	300

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

5-2 Work requirement

1) Preparation of Pavement Surface

Pavement surfaces adjacent to the pothole shall be cleaned by broom or an air jet, and free from puddle.

2) Application of Asphalt compound

Apply approximately 10 mm higher level of asphalt compound to each pothole, as recommended by each working instruction of manufacturer.

Photo5-5 Applied hot mix

3) Curing

After application, perform until the hot asphalt compound temperature become under 40℃. For cold mix asphalt compound shall be kept by each working instruction of manufacturer.

6. Measurement and Payment

6-1 Method of Measurement

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.

6-2 Basis of Payment

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.

Pay Item No.	Name	Unit of Measurement
2-5	pavement repair	Liter