IMPROVEMENT OF QUALITY MANAGEMENT FOR HIGHWAY AND BRIDGE CONSTRUCTION AND MAINTENANCE, PHASE II

BRIDGE REPAIR MANUAL

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Department of Public Works and Highways

Japan International Cooperation Agency

IMPROVEMENT OF QUALITY MANAGEMENT FOR HIGHWAY AND BRIDGE CONSTRUCTION AND MAINTENANCE, PHASE II

BRIDGE REPAIR MANUAL
(2ND EDITION)

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DEPARMENT OF PUBLIC WORKS AND HIGHWAYS

JAPAN INTERNATIONAL COOPERATION AGENCY

Republic of the Philippines
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
OFFICE OF THE SECRETARY
Manila

FOREWORD

Bridges have long served their purpose of connecting not just places that are miles apart, but people from all walks of life as well. Bridges stand as concrete and unyielding witness of Philippines' history: uniting people, renewing ties, and being a national symbol of strength amidst challenges.

While calamities have destroyed some of our major links, we remain firm and steadfast under all weathers and through all forms of both man-made and natural calamities moving together as we build back better and safer bridge structures.

Fittingly titled, **Bridge Repair Manual**, it contains guidelines on sustainable bridge inspection programs, and, standard methods and procedures on bridge inventory and condition surveys with systematic workflow and better time management.

An affirmation of the objective of building bridges that are not just structurally sound but also embodies the Philippines' resilience, may this Manual produced in cooperation with Japan International Cooperation Agency (JICA) be an effective tool for our engineers and technical personnel.

Our sincerest gratitude to JICA for their technical and funding assistance and the dedicated DPWH personnel who both worked hard in the realization of this Manual.

I enjoin all those concerned to use this as easy reference and proper guide in managing bridge repair.

ROGELIO L. SINGSON
Secretary

ACKNOWLEDGEMENT

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The JICA Expert Team would like to express its appreciation to the staff of Region VII and Region XI, and also its heartfelt thanks to the Technical Working Group and Counterpart Working Group members designated for the Project, who have rendered utmost support to complete this undertaking.

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ABBREVIATIONS

ASTM	:	American Society for Testing and Materials
AASHTO	:	American Association of State Highway and Transport Officials
BMS	:	Bridge Management System
BS	:	British Standard
CF	:	Concrete Failure
CFP	:	Carbon Fiber Plate
CFS	:	Carbon Fiber Sheet
CWG	:	Counterpart Working Group
DFT	:	Dry Film Thickness
DPWH	:	Department of Public Works and Highways
HTB	:	High Tension Bolt
HWL	:	High Water Level
JHS	:	Japan Highway Standard
JICA	:	Japan International Cooperation Agency
JIS	:	Japan Industrial Standard
JRA	:	Japan Road Association
KPa	:	Kilo-Pascal
MBA	:	Maintenance by Administration
MBC	:	Maintenance by Contract
MPa	:	Mega-Pascal
PC	:	Prestressed Concrete
PCDG	:	Prestressed Concrete Deck Girder
PhP	:	Philippine Peso
RC	:	Reinforced Concrete
RCDG	:	Reinforced Concrete Deck Girder
TWG	:	Technical Working Group
US$	:	United States Dollar
W/C	:	Water and Cement Ratio

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CHAPTER 1 INTRODUCTION

1-1 THE PURPOSE OF THIS MANUAL

The purpose of this manual is to describe and introduce standard repair methods against defects commonly found in bridges owned and maintained by DPWH. Both new repair methods and those that have been previously applied successfully to DPWH bridges are included in this manual. The following distinctive features are considered in view of standardizing the bridge repair manual:

- This serves as a guide for personnel responsible in selecting and implementing appropriate repair methods. This manual covers only the repairs of damaged bridge components. Reconstruction, total replacement or retrofit, requiring structural design, are not included in this manual
- The standard bridge repair methods are selected in consideration with structurally and practically acceptable methods in Philippines.
- The knowledge and experiences gained from pilot projects are also incorporated in this manual. This is an effective means of knowledge transfer to the maintenance engineers.

This manual serves as a guide for the repair works undertaken by DPWH, either through Maintenance by Administration (MBA) or Maintenance by Contract (MBC).

1-2 TARGET MANUAL USER

This manual is intended for;

- DPWH staff requiring guidance in selecting appropriate repair measures for bridges;
- Implementing staff of DPWH managing MBA or MBC;
- Maintenance staff of DPWH carrying out routine or major maintenance on bridges;
- Contractors of bridge repair works carried out through MBC.

1-3 STRUCTURE OF THIS MANUAL

The manual basically presents an introduction and standard bridge repair procedures, sub-divided into two parts namely, Routine Maintenance and Major Maintenance. The composition of the manual is as follows:

Chapter 1: Introduction

Part 1: Routine Maintenance

Chapter 2: Routine Maintenance Repair

Part 2: Major Maintenance

Chapter 3: Major Maintenance Repair

Chapter 4: Repair of Concrete Deck Slab

Chapter 5: Repair of Concrete Bridge Superstructure

Chapter 6: Repair of Concrete Bridge Substructure

Chapter 7: Repair of Steel Bridge Superstructure

Chapter 8: Repair of Bridge Expansion Joint

Chapter 9: Repair of Bridge Bearing

Chapter 10: Repair of Protection Works

The user's manual of computer program for selection of types of repair and detailed unit price analysis and cost estimates is included in this manual as an annex.

PART 1
ROUTINE MAINTENANCE

CHAPTER 2 ROUTINE MAINTENANCE REPAIR

2-1 TYPE OF DEFECTS AND CAUSES

Routine maintenance is conducted by DPWH District Engineering Offices. Defects and its causes should be given special attention by concerned DPWH staff.

Defects and its corresponding measures are listed as follows:

2-1-1 Steel Bridge Superstructure

Defects	Conditions	Photography	Causes/Measure
Paint Peel-off	1. Good Condition		Pinpoint rusting can occur at pinholes in the paint, which are tiny, deep holes in the paint exposing the steel. It can also be caused by thin paint coverage. Measure: Touch-up Painting

2-1-2 Concrete Bridge Deck Slab, Superstructure and Substructure

(1) Deck Slab

Defects	Conditions	Photography	Causes/Measure
Spalling/ Disintegration, Scaling	1. Fair 150mm<Width ≤ 300mm 25mm < Depth < 50mm		Initially, scaling has occurred and then spalling was caused by corrosion of rebars due to ponding water. Measure: Patching

(2) Concrete Superstructure

Defects	Conditions	Photography	Causes
Crack	1. Fair 0.3mm ≥ W 1 direction Spacing > 500mm		Shear cracks are caused by diagonal tensile forces that typically occur in the web of a member near the supports where shear stress is the greatest. Measure: Epoxy Coating

Defects	Conditions	Photography	Causes/Measure
Spalling/ Disintegration	1. Fair 150mm<Width ≤ 300mm & 25mm<Depth<50mm		As spalling is located at or near a maximum moment of girder, overstress may have occurred because girder is crushed Measure: Patching

(3) Concrete Substructure

Defects	Conditions	Photography	Causes/Measure
Spalling/ Disintegration	1. Fair 150mm<Width ≤ 300mm & 25mm<Depth<50mm		Rebars are exposed by spalling caused by impact due to drift woods. Measure: Patching

2-1-3 Bridge Accessories

(1) Bearing

Location	Defects	Photography	Causes/Measure
Bearing	1. Paint Deterioration and Corrosion		Surface rusting can occur at pinholes in the paint, which are tiny, deep holes in the paint, exposing the steel. It can also be caused by thin paint coverage. Measure: Repainting
	2. Debris Piling up around Bearing		Debris and sand is piled up around bearing due to opening on expansion joint Measure: Cleaning

(2) Expansion Joint

Location	Defects	Photography	Causes/Measure
Expansion Joint	1. Deterioration Sealant		The sealant joint is usually unprotected, when the edge of the deck is damaged the sealant deteriorates and peels-off. Measure: Cleaning and Resealing

2-1-4 Protection Works

Location	Defects	Photography	Causes/Measure
Abutment/ Pier	1. Accumulation of Debris		Drift woods, shrubs and weeds are piled up around pier due to short span, river course and shape of pier. This affects the flow of water along the channel Measure: Removal of Drift Wood
	2. Material Loss /Scouring		Stone materials are missing from stone masonry wall and gabion mattress due to strong river flow. Measure: Stone Masonry
	3. Damage on Gabion Wire		Gabion damage is generally due to destroyed wire mesh. Measure : Partial Replacement of Gabion Wire Mesh

2-2 ROUTINE MAINTENANCE ACTIVITIES

2-2-1 Responsible Office and Personnel

The district offices are responsible for routine maintenance with preventive repairs. Routine maintenance team is normally composed of 2 engineers and 6~8 skilled or semi-skilled workers. It is important that they are trained to perform above preventive repairs in order to prolong the service life of the bridges.

Routine maintenance is combined with bridge inspection and preventive maintenance. Preventive maintenance is classified as follows:

For steel superstructure:

- Pressure washing on the beams/girders.
- Touch-up paint to minor defects in the paint system such as scratches and small areas of corrosion

For concrete superstructure/substructure

- Patching of spalled/scaled areas on the concrete
- Epoxy coating of cracks with sealant.

For protection works

- Removal of mud, sand and debris on the pier and abutment and cleaning of bearing
- Removal of drift wood materials.

2-2-2 Equipment and Repair Materials

Maintenance activity cannot be performed without appropriate equipment/tools**.** Hence**,** it is necessary that equipment/tools, as shown in Figure 2-1, are provided for each district office.

High Pressure Water Blaster

Electric Grinder

Handy Electric Chisel

Portable Generator

Figure 2-1 Standard Equipment for Routine Maintenance

The following materials necessary for routine maintenance works should be kept readily available in each district office:

- Non-shrinkage cement
- Special anti-corrosion paint
- Aluminum paint
- Epoxy sealant
- Epoxy Primer

2-2-3 Repair Activities

For the repair activities during routine maintenance, the district office and their maintenance staff should identify the works classified under preventive repair, to prolong the service life of a bridge. In this manner, repairs could be implemented at the early stage of defects. The following are the concept of repair activities under routine maintenance:

(1) Steel Superstructure

Steel trusses and girders should be washed using high pressure water jet once every year during the dry season, especially those bridges located near the seaside. This is important to prevent rusting on the steel surface as most steel bridges near the sea have corroded due to salt contamination.

If rust or peeled-off paint occurs on steel surface, touch-up painting with either aluminum or anti-corrosion paint should be immediately applied during the dry season. It is important that the touch-up painting is carried out while the steel surface is still in good condition and have not yet exhibited corrosion.

Severe corrosion with section loss is often observed at steel girder ends, around the bearings. This corrosion is due to water seeping through defective deck expansion gaps. If this condition is observed, anti-corrosion paint should be partially applied at the girder ends to prevent rust from progressing.

(2) Concrete Superstructure/Substructure

Regarding concrete structures, responsibilities of district office and their maintenance staff are limited only to minor defects such as spalling and scaling, and not severe cracks. Such defects can be easily repaired with simple tools and materials shown in Section 2.2.2.

Patching is applied to small defects due to spalling and scaling. The repair works is simple and less costly; however, if accessibility to the defects is difficult, depending on the configuration of the structure and its surrounding landscape. Then, the required scaffolding should be assembled prior to the commencement of repair works. In case the defects are located in deep water or at high elevations, an inspection vehicle equipped with scaffolding should be used.

Epoxy coating is applied to prevent penetration of water through cracks. Type of crack should be identified whether it is due to structural failure or not, and active or inactive. This assessment could be difficult in the routine maintenance level. Nevertheless, surface cracks should be repaired with epoxy coating to prevent penetration of water. Subsequently, progress of crack width should be monitored.

(3) Bridge Accessories

If the expansion joint on the bridge deck is defective, debris, sand and water pass through the gaps and eventually deposited to piers and abutments. Hence, repair or replacement of expansion joint should be carried out. Prior to this, stocked contaminants should be washed out from the gaps using high pressure water jet. Subsequent cleaning

should be performed once a year, preferably during the dry season.

(4) Protection Works

The shortness of the span, nature of river course, shape and location of piers, may cause drifting woods, shrubs and weeds to pile up at the upstream side of the pier. Removal of debris and manual cleaning is recommended.

2-2-4 Routine Maintenance Cost

If the district office and its staff can manage and properly implement the routine maintenance activities, the service life of the bridge can be prolonged without spending high costs for repair and reconstruction.

Routine maintenance is a preventive measure. It should be undertaken at an early stage which require only minor repair tools and materials

2-3 SCOPE OF ROUTINE MAINTENANCE AND REPAIR METHOD

2-3-1 Cleaning

2-3-1-1 Description of Method

To prevent deterioration of the bridge structure, cleaning works should be performed including removal of all accumulated foreign materials from the entire bridge such as its deck, sidewalk, curbs, top of pier, trusses and its web members, lower flanges of beams or girders, cleaning of expansion joints, bearings, wind bracing and drains. Areas which have been cleaned shall be ensured free from accumulated sand, gravel, dirt, and other foreign materials.

Photo 2-1 Cleaning of Bearing

Photo 2-2 Cleaning using Inspection Vehicle

2-3-1-2 Application Criteria

The bridge shall be maintained clean and in good condition to prolong its service life, as well as to provide safety and comfort to road users. Criteria for cleaning applied to the bridge including its steel surface, deck and substructure are recommended as follows:

(1) Surface of Steel Plate

All surface areas of a steel bridge should be cleaned, including the top and bottom flanges, web plates, diaphragms, lateral members and gusset plates. This should be washed using high pressure water blasting. Inspection vehicle should be utilized to conveniently carry out cleaning of the bridge soffit.

(2) Bridge Deck Slab

All surface areas of the bridge deck should be cleaned, including the curbs, expansion joints, drain pits and railings. This could be performed using high pressure water blasting or manual shoveling/sweeping.

(3) Bridge Substructure

All areas of the under the superstructure should be cleaned, including the bearings, parapet wall, pier caps and concrete diaphragms. This could be executed using high pressure water blasting or manual shoveling/sweeping. In case of difficulty in accessing the top of piers, inspection vehicle should be utilized and installed at a higher position.

2-3-1-3 Work Sequence

(1) Surface of Steel Plate

All foreign materials such as dirt, dust, rust, scale, sand, and moss on steel surface shall be completely removed manually.

Steel plate shall be cleaned by washing out chlorides or other chemical deposits known to accelerate corrosion. Washing with high pressure water bluster to completely remove all toxic substance is carried out from top to bottom and from end to the center of the steel girder as shown in Figure 2-2. Steel girders located near the sea are often cleaned especially the bottom surface of lower flanges.

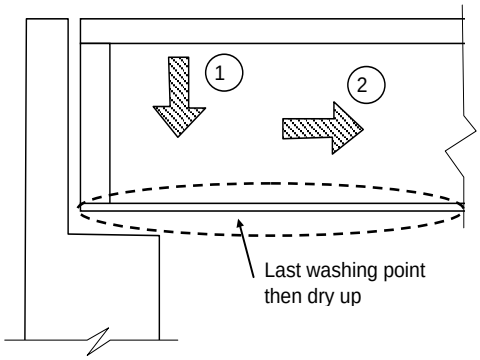


Figure 2-2 Sequence of Cleaning Girders

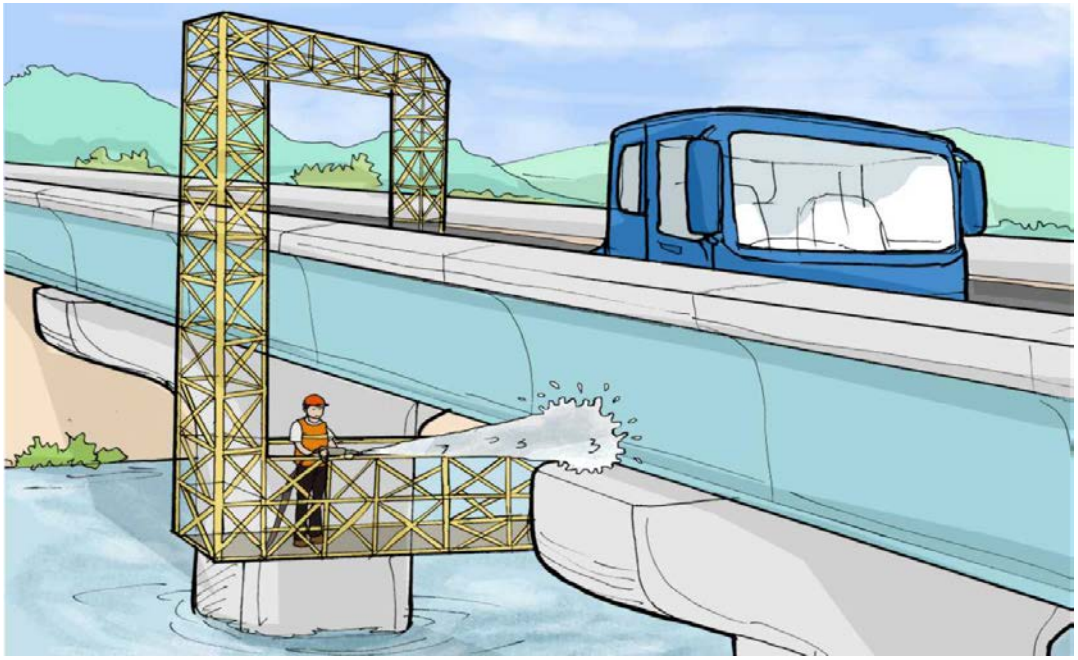


Illustration 2-1 Cleaning of Steel Girder

(2) Bridge Deck Cleaning

All foreign materials such as dirt, dust, sand, rain water, and moss on concrete surfaces and at the gaps between girders shall also be completely removed manually and then washed using a high pressure water bluster. The following areas on the deck should also be carefully cleaned:

- Expansion joints
- Drainage

Photo 2-3 Vegetation in the Deck or Girder

Photo 2-4 Joint is Clogged with Sand and Dust

Photo 2-5 Ponding Water on the Deck

Illustration 2-2 Cleaning of the Deck Slab and its Drainage Inlet

(3) Cleaning of Bridge Substructure

All foreign materials such as dirt, dust, sand, rain water, and moss on surfaces of abutment and pier bearing seats and coping shall also be completely removed manually and then washed using a high pressure water bluster. Mud and sand deposits at the sides of abutment shall be excavated to maintain its original distance from the river bank.

Photo 2-6 Mud, Debris & Sand on Bearing

Photo 2-7 Vegetation on the Substructure

Illustration 2-3 Cleaning of Bearings

Illustration 2-4 Removal of Grass and Shrubs near the Bridge

2-3-1-4 Required Materials and Tools/Equipment

Cleaning equipment shall consist of hand tools, high pressure water blaster, water tanks, and water pumps with associated delivery hardware necessary to properly flush, clean, and remove all foreign materials from the bridge structure. Other types of cleaning equipment may also be used subject to the approval of a designated Engineer. Clean water is recommended.

Other equipment such as inspection vehicle installed under the bridge, access trucks or movable scaffolding devices may be necessary to access the areas to be cleaned.

2-3-1-5 Specifications

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.

The high-pressure water shall be sufficient to remove salt contaminants, dirt, and other detrimental foreign matters without damaging or peeling the paint from any structural steel. The minimum flow rate of water for cleaning the bridge components shall be approximately 10 liters per minute. The maximum water pressure shall be 8000 KPa, but not so high that any paint is removed. The cleaning operation shall be discontinued if the foreign materials have not been easily removed or if cleaning operations are 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. Drain 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 the source of water used. The Contractor shall use fresh water which is free of sediments and salt contaminants. The Contractor shall be responsible for all expenses involved in securing the proper water.

2-3-1-6 Measurement and Payment

(1) Method of Measurement

Bridge cleaning shall be considered as a lump sum item.

(2) Basis of Payment

For bridge cleaning, the Contractor shall be paid the 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.

2-3-2 Touch-up Painting

2-3-2-1 Description of Method

Work under this item shall consist of field touch-up painting on steel at localized areas. This work also includes containment, surface preparation, and collection and storage of all paint debris.

Touch-up painting is done to prevent corrosion. This work only covers painting to small areas where hand and power tool preparation is the only feasible method. Large areas, where sand blast cleaning can be justified, should be painted in accordance with the repainting procedure as discussed in Section 7-1.

2-3-2-2 Application Criteria

Touch-up painting should be partially applied to rusted steel plate as shown in the following photos.

Affected surface area is 10 to 20% in a member

Affected surface area is 20 to 30% in a member

Photo 2-8 Steel Surface Affected by Corrosion

3rd Grade Surface preparation is applied as shown in the following Table 2-1.

Table 2-1 Preparation Grades of the Surface on Corroded Steel Plate

Grade	Rust Conditions	Working Process	Photograph (After Preparation)
3rd Grade	Corrosion is partially severe on steel surface and coating film is almost visible but partially deteriorated due to corrosion. Affected surface area is 20 to 30%	Old coating film, rust is removed with scraper and wire brush, partially revealing the steel texture.	
4th Grade	Corrosion is partially visible but not severe. Peeled-off coating film is partially visible. Affected surface area is 10 to 20%	Old coating film, rust is removed with disc grinder, scraper and wire brush.	

If paint condition is evaluated as 4th Grade "Poor condition," with an affected area of 10 ~ 20%, aluminum paint shall be applied with similar color shade. If paint condition is evaluated as 3rd Grade or "Poor condition," with an affected area of 20 ~ 30% and section loss of less than 20%, special anti-corrosion paint shall be applied to prevent further corrosion.

Photo 2-9 Touch-up Paint to Corroded Portion

Photo 2-10 Surface of Touch-up Paint

Special anti-corrosion paint systems should be also used for galvanized and heavily corroded steel surfaces. Ordinary selected patch paint such as aluminum-painting is not suitable for galvanized surfaces. (Old steel truss bridges manufactured in USA are made up of galvanized metal). The special anticorrosion paint should be applied to heavily corrode steel portion as shown in the photos.

2-3-2-3 Work Sequence

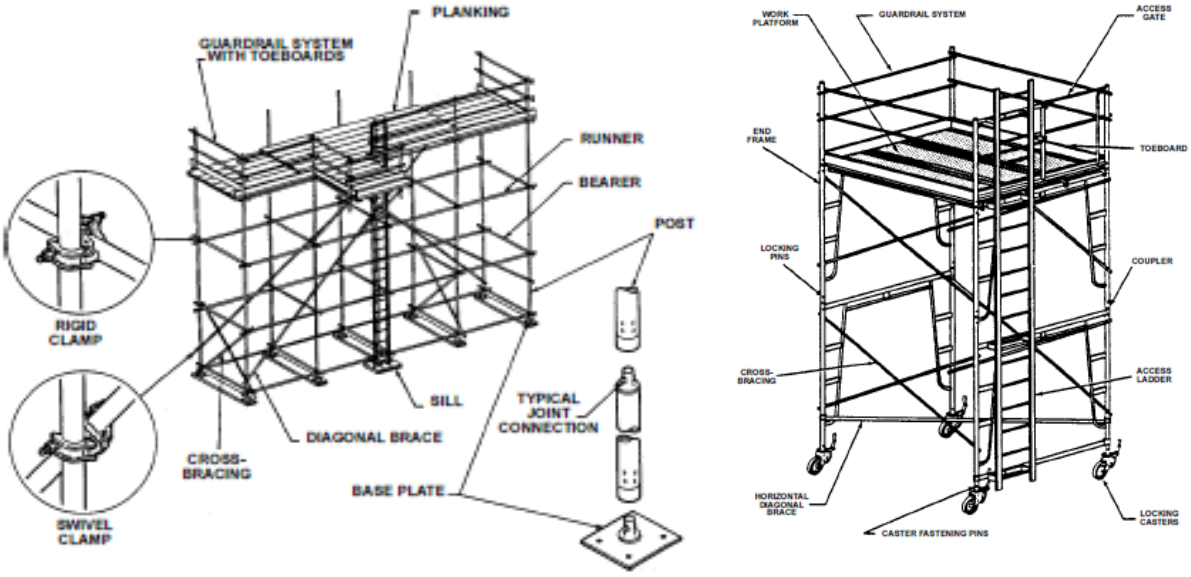
(1) Scaffolding

Prior to touch-up painting work, scaffolding should be installed at the side of the structure. Independent scaffolding is also appropriate for repair works. This consists of two standard types, connected longitudinally and transversely. These standard scaffoldings shown in Figure 2-3 are normally used in repair works.

Birdcage scaffolding is a stationary type built around an abutment and pier or, near a defective area. Movable scaffolding meanwhile allows movement to any direction, hence, are commonly used for repainting/touch-up painting for truss-type bridges. Inspection vehicle with scaffolding device can also be utilized at locations where accessibility is difficult, such as for bridges with high elevation or at deep river crossings.

Illustration 2-5 Touch-up Painting Utilizing Bridge Inspection Vehicle

Scaffolding can be installed at sites with topographic uneven terrain. Steel pipe scaffolding is popular. Its assembling sequences should comply with manufacture's manual.



Birdcage Scaffolding Movable Scaffolding

Figure 2-3 Independent Scaffolding for Repair Work

(2) Preparation of the Steel Surface

The steel surfaces for touch-up painting should be prepared in accordance with the recommendations from the manufacturer of the required paint system. Hand or power tool cleaning is the minimum requirement described in Table 2-1 for 3rd Grade paint condition.

Sharp ridges and deep narrow grooves or pits shall be removed from the steel surface using power grinder. Alternatively, for surfaces with site fillet welds, fill the surface to a smooth even finish using epoxy resin fillers such as those used for void filling described in Subsection 7-1-3-3. However, where depth of roughness is less than 0.5 mm adequate and durable paint system can be achieved without multiple coats of surface leveling paint. Each coat shall not be more than the maximum film thickness recommended by the manufacturer.

(3) Touch-up Painting

Paint shall be applied using brush or roller. The paint shall be applied to produce a uniform smooth coat without runs, streaks sags, wrinkles, or other defects. The paint components shall be mixed properly and applied in accordance with the manufacturer's instructions. The paint shall be applied immediately after surface preparation, preferably within 4 hours on the same day. The minimum total dry film thickness of the system should not be less than 125 micrometers (Aluminum Paint) and 500 micrometers (Special anti-corrosion paint).

2-3-2-4 Required Materials and Tools/Equipment

(1) Required Materials

- Aluminum Paint (locally available)
- Thinner
- Special Anti-corrosion Paint

(2) Required Equipment/Tools

- Power Disk Grinder (Portable type) / Sand Paper
- High Pressure Water Blaster (8.0Mpa, 10.0 liters/min.)
- Portable Generator (3.0 kVA)
- Paint roller (handy type) and Brush
- Scaffolding or Inspection Vehicle

2-3-2-5 Specification

(1) Material Requirement

The special anti-corrosion paint used for touch-up coating shall conform to the requirements of the specifications in Table 2-2, or equivalent to ASTM Specifications.

Table 2-2 Specification of Special Anti-Corrosion Paint for Touch-up Coating

Property	Test Method	Unit	Specification
Adhesive test	JIS A6909/ASTM D7234	N/mm2	7days 1.0, 28days 1.5
Elongation	ASTM C190	%	7days 0.40, 28days 0.40
Saltwater test	JIS K5600/ASTM D6943		Not detected

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

Aluminum paint is in accordance with DPWH Standard Specifications Item 709.

(2) Construction Requirement

The construction requirement for re-painting shall be performed in accordance with DPWH Standard Specification Item 411- PAINT, except for the following:

Surface Preparation

The minimum surface preparation for small areas shall be as specified in this repair manual, using hand or power tool cleaning, applicable to 3rd grade condition, as stated in sub-section 2-3-2-2.

Touch-up Painting Application of Special Anti-corrosion Paint

The total dry film thickness (DFT) of special anti-corrosion paint shall be 500 μ m (equivalent 1.5kg/m2) consisting of two layers of coating as follows:.

- 1st layer: 250 μ m
- 2nd layer: 250 μ m

Detailed application of special anti-corrosion paint is discussed in Section 7-5 of this manual.

Aluminum paint meanwhile shall be in accordance with DPWH Standard Specifications, Item 709.3.1.

2-3-2-6 Measurement and Payment

(1) Method of Measurement

This work will be measured for payment by the actual area in square meters of steel surfaces cleaned, painted and accepted.

(2) Basis of Payment

This work will be paid based on a unit price per square meter for "Field Touch-up Painting", complete in place, which shall include all materials, containers, equipment, tools, labor, services of the technical service advisor, and work incidental for the touch up painting of the structure. There will be no direct payment for the cost of storage or hauling of the paint and other materials to and from the bridge or bridges to be painted, or for the containment, collection, and storage of hazardous or contaminated materials within the work areas. The cost thereof shall be deemed included in the price per square meter.

2-3-3 Epoxy Coating on the Crack

2-3-3-1 Description of Repair Method

This work item is applicable to repair of vertical or overhead cracks, with widths of less than 0.3 mm.

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.

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.

Photo 2-11 Epoxy Coating Penetrating into the Crack

2-3-3-2 Application Criteria

Cracks with widths of less than 0.3 mm, is acceptable if the cause is non-structural, and has no adverse effect on the structure. However, it is difficult during routine maintenance to evaluate whether the crack is stable or developing due to such factors as carbonation, chlorination, corrosion, overloading of structure, insufficient reinforcement or inadequate concrete cover.

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 if crack formation is structural or non-structural. Subsequently, the district office should regularly monitor the cracks for future repair, if necessary.

2-3-3-3 Work Sequence

(1) Preparation of Concrete Surface

Concrete surfaces adjacent to the crack shall be cleaned by air jet, and free from laitance and contaminants such as grease and oil.

(2) Application of Epoxy Sealant

Apply approximately 50 mm width strips of epoxy sealant coating to concrete surfaces along the crack, as recommended by the manufacturer.

(3) Curing

After application, perform until the epoxy coating hardens.

(4) Monitoring of Crack width

The cracks coated with sealant shall be monitored by a designated maintenance staff

of the district office, to determine whether it is progressing or not.

2-3-3-4 Required materials and Tools/Equipment

(1) Required Materials

- Epoxy Sealant

(2) Required Equipment/Tools

- Brush or Paint Roller

2-3-3-5 Specification

(1) Material Requirement

The epoxy material shall conform to the requirements of the specifications in Table 2-3.

Table 2-3 Specification of Epoxy Sealant for Coating

Property	Test Method	Unit	Specification
Viscosity	JIS K 6833/ASTMD2393	mPa-s*	500 below
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM D7234	N/mm^2	1.5
Slant Shear Bond Strength	JIS K6852/ASTM C882	N/mm^2	15

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

* milliPascal-second

(2) Construction Requirement

This repair method is the simplest and most common technique for crack repair and can be done by a relatively unskilled laborer. It is suitable for fine pattern cracks, but will not be effective on active cracks and those subject to movement due to applied loads and temperature changes.

The purpose of the 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.

2-3-3-6 Measurement and Payment

(1) Method of Measurement

This work shall be measured for payment by the actual length in linear meters of the cracks where epoxy coating is applied, as determined and approved by the engineer.

(2) Basis of Payment

This work will be paid based on a unit price per linear meter for the crack 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 concrete and application of epoxy coating, as specified on plans and specifications, and as directed by the engineer.

2-3-4 Patching

2-3-4-1 Description of Repair Method

Patch repair 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. The patch thickness is limited to a maximum of 100 mm depth of hollow surface.

Type A Patching is for defects without exposed rebars while Type B Patching is applied to surfaces with exposed rebars.

Patch repairs may be composed of Portland cement mortars or polymer cement mortar, depending on the type of patching, location and extent of damage.

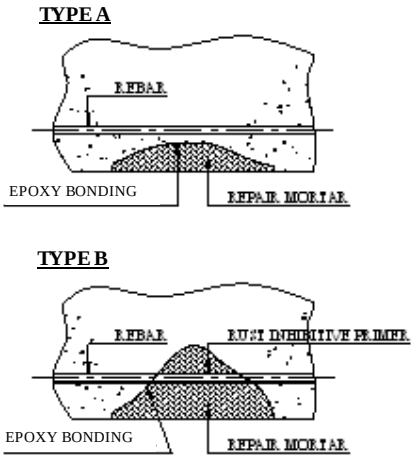


Figure 2-4 Type of Patching

2-3-4-2 Application Criteria

Patch repair is classified into two types, considering the characteristics of the defective area and surface. Type-A is applicable to surfaces without exposed rebars, having defective widths of up to 300 mm and depth up to 50 mm. Type-B meanwhile is for surfaces with exposed rebars, with defective width between 300 mm and 600 mm, and up to 100 mm depth and shall not to exceed 50% of depth of deck slab Type-A repair is included in the routine maintenance while Type-B is excluded since it involves major repair, considering the size of the repair area.

Type-A involves application of either Portland cement mortar or polymer cement mortar, for both horizontal and vertical surfaces.

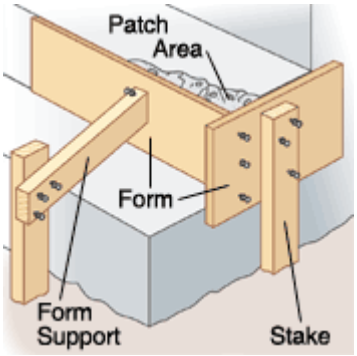
2-3-4-3 Work Sequence

(1) Remove Loose Debris

Using a small sledge hammer and chisel, remove all damaged concrete at corner edges of area to be repaired. Use a wire brush to remove loose debris.

(2) Furnishing Formwork

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



(3) Coating Bonding Agent or Setting Nail

Apply bonding agent to the damaged area in order for the patch material to adhere, or set concrete nails/bids to reinforce the repair. If rebar is exposed, anticorrosion agent coating on the bar surface should be applied prior to patching.

(4) Placing Cement Mortar

Prepare the mortar mix in a bucket. 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. It should be noted that polymer cement mortar is suitable for both vertical or horizontal surface applications, with a thin coating of up to 15 mm. As may be required, it can be smoothened using a trowel or broom finished.

(Horizontal Finish)

(Vertical Finish)

(5) Curing

All types of concrete repair need thorough and continuous curing to develop strength and impermeability. Curing also minimizes drying shrinkage while bond strength is developing.

2-3-4-4 Required Materials and Tools/Equipment

(1) Required Material

Portland Cement Mortar	**Polymer Cement Mortar (PCM)**
- Portland Cement	- PCM Powder
- Sand	- PCM Emulsion
- Water	- Concrete Nail
- Concrete Nail	- Bonding Agent to Concrete (Epoxy Bonding)
- Bonding Agent to Concrete (Epoxy Bonding)	

(2) Required Equipment/Tools

- Chisel
- Portable Generator
- Wire Brush
- Small Hammer
- Mortar Mix Bucket
- Safety goggles
- Trowel
- Scaffolding or Inspection Vehicle

2-3-4-5 Specifications

(1) Material Requirement

Portland Cement Mortar shall conform to the requirements of Item 405, Structural Concrete, DPWH Standard Specifications. Strength test for Portland cement mortar shall be based on ASTM C 780

Polymer Cement Mortar (PCM) shall conform to the requirements of the specifications indicated in Table 2-4.

Table 2-4 Specification of Polymer Cement Mortar for Patching

Property	Test Method	Unit	Specification
Compressive Strength	JSH 416/ASTM C39	N/mm^2	At 28 days: ≥ 25
Bonding Strength to Concrete	JHS 416/ASTM D 7234	N/mm^2	≥ 1.5
Bleeding Rate	JHS 416/ASTM C 39	%	0

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

The epoxy bonding agent to concrete surface shall conform to the requirements of the specification indicated in Table 2-5. (Anti-corrosion zinc rich primer shall be applied to exposed rebar).

Table 2-5 Specification of Epoxy Bonding Agent to Concrete Surface

Property	Test Method	Unit	Specifications
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	70
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	40
Tensile Strength	JIS K 7113/ASTM D638M	N/mm^2	30
Tensile Shear Bond to Steel	JIS K 6850/ASTM D1002	N/mm^2	15
Slant Shear Bond to Mortar	JIS K6852/ASTM C882	N/mm^2	15
Bond Strength of Cured Concrete to Fresh Concrete	JIS K5400/ASTM D7234	N/mm^2	15

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

(2) Construction Requirement

Patching repair works using Portland cement mortar shall be carried out in accordance with relevant provisions of the DPWH Standard Specifications. Patching, as a minor repair work, should be carried out using an inspection vehicle as shown in Photo 2-12, before the defect worsens.

Photo 2-12 Patching Repair using Inspection Vehicle

Patching repair work method using polymer cement mortar is as follows:

Removal of Damaged Concrete

Old concrete within marked out areas shall be removed using light mechanical breakers or hammer and chisel. Surface shall be cut to expose the reinforcement and the sound concrete substrate, without breaking the concrete behind the reinforcement. All works shall be subjected to the approval of the designated engineer.

Concrete Surface Preparation

All concrete surfaces that are to receive repair mortar shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss. It shall then be coated by a bonding primer. Care shall be taken to ensure that vibration from the method of preparation does not cause delamination of existing adjacent plaster or concrete.

Method of Placing Mortar

The repair mortar shall be mixed using equipment type (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. To help the patch adhere, the damaged area is coated with a bonding agent or concrete nails/bids are set to reinforce the repair. The mortar shall then be applied to the same surface using hand packing and trowel. The textured 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 a technical data to justify a layer thickness of greater than 20 mm.

Curing and Inspection

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.

2-3-4-6 Measurement and Payment

(1) Method of Measurement

The engineer will measure the area prepared for patching by the square meter, after the designated thickness of surface has been removed. The measured pay quantity will include the marked areas and delaminated concrete identified by the engineer.

(2) Basis of Payment

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

2-3-5 Removal and Disposal of Driftwoods and Plants

2-3-5-1 Description of Works

The works involve removal of driftwoods around piers and disposal to a designated area.

Photo 2-13 Accumulated Drift Wood and Plants around Pier

2-3-5-2 Application Criteria

It is essential to remove the driftwoods and debris lodged on the piers during the early stage of routine maintenance, otherwise it will become more difficult to dislodge, increasing the risk of bridge or slope failure. The removal and disposal of driftwoods and debris shall be carried out once a year, or after occurrence of floods when necessary.

2-3-5-3 Work Sequence

Driftwoods and debris shall be removed and properly disposed to a designated disposal area. Large driftwoods are cut at the site and properly disposed,

No burning of driftwoods or debris is permitted within the limits of the highway right of way. These are stockpiled for drying at the disposal area.

If there is difficult to access the driftwood and debris piled around the pier, scaffolding is necessary to install for its removal. Inspection vehicle with scaffolding device can be utilized.

Illustration 2-6 Removal of Drift Wood around Piers

2-3-5-4 Required Materials and Tools/Equipment

(1) Required Materials

None

(2) Required Equipment/Tools

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

2-3-5-5 Measurement and Payment

(1) Method of Measurement

This works will be measured by cubic 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 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.

2-3-6 Partial Replacement of Stone Masonry

2-3-6-1 Description of Works

The works involve restoration of the missing stones from masonry and gabion mattress.

Photo 2-14 Missing Stone on Wet Masonry

2-3-6-2 Application Criteria

It is essential to replace the broken gabion and slope protection with stone during the early stage of routine maintenance; otherwise it will become more difficult to repair the damages, increasing the risk of slope failure. The stone patching shall be carried out when necessary.

2-3-6-3 Work Sequence

The damaged stone masonry at limited areas shall be immediately repaired before condition worsens. The damaged area is replaced by installation of new stone masonry according to alignment and dimensions as shown in the drawings.

All unsound, imperfect or loose stones and mortar joint, panel, etc. shall be removed. The substrata shall then be compacted as preparation of the base. The slope line shall be carefully prepared at the same level as also shown in the drawings.

Stones shall be laid in full bed of mortar, with joints completely filled with mortar and shove into place. If necessary to move or shift unit already laid, remove the setting mortar, then clean and apply new fresh mortar for final placement. Coursing and mortar joints must be done as directed by the engineer. Stone must be laid and anchors must be installed in accordance with the drawings.

Where new stone masonry is placed to 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.

Except as specified hereunder, work sequence and specifications shall be in accordance with DPWH Standard Specification Item 506-Stone Masonry.

2-3-6-4 Required Materials and Tools/Equipment

Materials and tools/equipment required for the works shall be performed in accordance with DPWH Standard Specification Item 506-Stone Masonry.

2-3-6-5 Measurement and Payment

Method of measurement and payment required for the works shall be in accordance with DPWH Standard Specification Item 506-Stone Masonry.

2-3-7 Partial Replacement of Gabion Wire Mesh

2-3-7-1 Description of Works

The Gabion Mattress protects abutment and pier in front of them. Gabion Wire is destroyed by strong river flow during rainy season.

Photo 2-15 Partially Deteriorated Gabion Wire

2-3-7-2 Application Criteria

It is essential to replace the broken gabion wire during the early stage of routine maintenance; otherwise it will become more difficult to repair the damages, increasing the risk of Gabion failure.

2-3-7-3 Work Sequence

The damaged gabion wire at limited areas shall be immediately repaired before condition worsens. The damaged area is replaced by installation of new gabion wire according to DPWH Standard Specification Item 511-Gabions and Mattresses.

2-3-7-4 Required Materials and Tools/Equipment

Materials and tools/equipment required for the works shall be performed in accordance with DPWH Standard Specification Item 511- Gabions and Mattresses.

2-3-7-5 Measurement and Payment

Method of measurement and payment required for the works shall be in accordance with DPWH Standard Specification Item 511- Gabions and Mattresses.

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PART 2
MAJOR MAINTENANCE

→

CHAPTER 3 MAJOR MAINTENANCE REPAIR

3-1 TYPES OF DEFECTS AND CAUSES

Types of defects and causes are classified based on the condition rating criteria combined with the relevant stipulations in the Bridge Inspection Manual of the Bridge Management System (BMS) in the DPWH. The rating criteria classifies the bridge component into four conditions, namely Good, Fair, Poor and Bad, based on the results of the condition inspection. In the bridge repair manual, the defects are focused on fair, poor or bad classifications, with corresponding causes identified. Typical defects are shown in the photographs of selected bridges in the Philippines. The types of defects and causes are classified for each of the following bridge components:

- Steel Bridge, Superstructure
- Concrete Bridge, Deck Slab
- Concrete Bridge, Superstructure
- Concrete Bridge, Substructure
- Bridge Accessories such as Expansion Joint and Bearing
- Protection Works

3-1-1 Steel Bridge, Superstructure

The common defects that occur on superstructure of steel bridges are shown in Table 3-1.

Table 3-1 Common Defects on Superstructure of Steel Bridge

Defects	Conditions	Photography	Causes
Corrosion	1. Without Section Loss (Good to Fair)		Corrosion is the primary cause of section loss in steel members and is most commonly caused by the wet-dry cycles of exposed steel.
	2. With Section Loss (Poor to Bad)		In coastal areas where salt concentration is present, the effect of corrosion is accelerated and section loss will develop if there is no maintenance.
Paint Peel-off	1. Good Condition to Fair Condition		Pinpoint rusting can occur at pinholes in the paint, which are tiny, deep holes in the paint, exposing the steel. It can also be caused by thin paint coverage.
	2. Affected Condition (Poor to Bad)		Environmental corrosion primarily affects metal in contact with sea water and is caused by formation of a corrosion seal.
Other Damages	1. Loose Connection (Poor to Bad)		High Tension Bolts (HTB) connecting web plate are missing (maybe due to fatigue, vibration or may have been stolen. It is necessary to replace HTB for structural stability
	2. Heat Damage		Steel members undergo serious deformation upon exposure to fire or extreme heat. In addition to sagging, or elongation of steel, intense heat often causes members to buckle and twist.

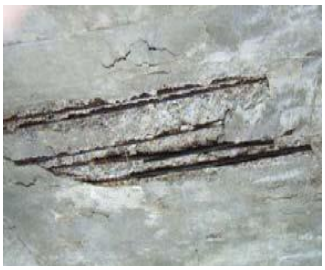
3-1-2 Concrete Bridge, Deck Slab

The common defects on concrete deck slab are shown in Table 3-2 and Table 3-3.

Table 3-2 Common Defects on Concrete Deck Slab (1/2)

Defects	Conditions	Photography	Causes
Cracking	1. Fair Crack width < 0.3mm in 1 direction only; Spacing ≥ 500mm		At first, transverse cracks are caused by shrinkage of concrete in the longitudinal direction.
	2. Poor Crack width > 0.3mm to ≤1mm;2 directions; Spacing ≥ 200mm to < 500mm		Longitudinal cracks are caused by bending stress of Live load. After increasing cracks , 2 directional cracks mixed to make crocodile type cracks.
	3. Bad Crack width > 1mm; 2 directions; Spacing < 200mm		Increasing cracks caused water leakage. The deterioration of slab is accelerated by water leakage. cracks so that concrete and rebar may be deteriorated.
Spalling/ Disintegration/ Scaling	1. Fair Affected area > 150mm to ≤ 300mm wide in any direction or depth is > 25mm to ≤ 50mm		At first, scaling is occurred and then spalling can be caused by corroding rebars due to standing rain water.
	2. Poor Affected area > 300mm to ≤ 600mm wide in any direction or depth is > 50mm to ≤100mm		Expansion of rebar by severe corrosion caused spalling of slab especially near sea by wind borne sea water spray. because surface concrete damaged looks like a crush in
	3. Bad Affected area > 600mm wide in any direction or depth is > 100mm		Expansion of rebar by severe corrosion caused spalling of slab especially near sea by wind-borne sea water spray. rebar.
			Scaling is the gradual and continuing loss of surface mortar and aggregate over an area due to the chemical breakdown of the cement bond due to rain and traffic

Table 3-3 Common Defects on Concrete Deck Slab (2/2)

Defects	Conditions	Photography	Causes
Rebar Exposure/ Corrosion	1. Fair Main rebar exposed & corroded or flaked; Area ≤ 50cm^2 Wide		Spalling is caused by rebar expansion. The rebar are exposed and severe corrosion occur later after spalling. occurred at tension area of bottom of deck slab center.
	2. Poor Main rebar exposed & corroded; Area > 50cm^2 to ≤ 100cm^2		
	3. Bad Main rebar exposed & corroded; Area > 100cm^2; with section loss		The cause of defect is the same as the above, but water is continuously leaking from slab surface, concrete is severely deteriorated resulting to detachment of a fragment of concrete.
			The cause of defect is same as the above, but section loss has developed severely.
Honeycomb	1. Fair Affected area is >150mm to ≤ 300mm wide in any direction		Honeycomb is caused by incomplete/improper vibration during pouring concrete. The aggregate and cement mortar is insufficiently mixed
	2. Poor Affected area is >300mm to ≤ 600mm wide in any direction		
	3. Bad Affected area is > 600mm wide in any direction	None	

3-1-3 Concrete Bridge, Superstructure

Common concrete defects of bridge superstructure are shown in Table 3-4 and Table 3-5.

Table 3-4 Common Concrete Defects of Bridge Superstructure (1/2)

Defects	Conditions	Photography	Causes
Cracking	1. Fair Crack width < 0.3mm in 1 direction only; Spacing ≥500mm		Shear cracks are caused by diagonal tensile forces that typically occur in the web of a member near the supports where shear stress is the greatest.
	2. Poor Crack width > 0.3mm to ≤1mm;2 directions; Spacing ≥ 200mm to < 500mm		
	3. Bad Crack width > 1mm; 2 directions; Spacing < 200 mm		Shear cracks are caused by shear force of bearing that tip area of steel bearing is limited where shear stress is the greatest.
Spalling/ Disintegration/ Scaling	1. Fair Affected area > 150mm to ≤ 300mm wide in any direction or depth is > 25mm to ≤ 50mm		As spalling is located at or near center span of the girder, it is affected by wind-borne sea water spray
	2. Poor Affected area > 300mm to ≤ 600mm wide in any direction or depth is > 50mm to ≤100mm		As spalling is located at or near seat of bearing, impact due to traffic may have occurred since concrete of girder is crushed.
	3. Bad Affected area > 600mm wide in any direction or depth is > 100mm		As spalling is located at or near center span of the girder, it is affected by wind-borne sea water spray

Table 3-5 Common Concrete Defects of Bridge Superstructure (2/2)

Defects	Conditions	Photography	Causes
Rebar Exposure/ Corrosion	1. Fair Main rebar exposed & corroded or flaked; Area ≤ 50cm^2 Wide		Spalling may be caused by corrosion of rebar exposed due to water leakage or restriction of thermal movement due to a faulty bearing position.
	2. Poor Main rebar exposed & corroded; Area > 50cm^2 to ≤ 100cm^2		As spalling is located at or near center span of the girder, it is affected by wind-borne sea water spray.
	3. Bad Main rebar exposed & corroded; Area > 100cm^2; with section loss	 	As spalling is located at or near center span of the girder, it is affected by wind-borne sea water spray.
Honeycomb	1. Fair Affected area is >150mm to ≤ 300mm wide in any direction		Honeycomb is caused by lack of mortar in the spaces between coarse aggregate particles which is due to insufficient compaction or vibration during placement of concrete
	2. Poor Affected area is >300mm to ≤ 600mm wide in any direction		
	3. Bad Affected area is > 600mm wide in any direction		

3-1-4 Concrete Substructure

The common concrete defects of bridge substructure are shown in Table 3-6, Table 3-7 and Table 3-8.

Table 3-6 Common Concrete Defects of Bridge Substructure (1/3)

Defects	Conditions	Photography	Causes
Cracking	1. Fair Crack width < 0.3mm in 1 direction only; Spacing ≥ 500mm		Cracks are caused by shrinkage of concrete during the curing process. But main cause of cracking is due to the effect of sea water.
	2. Poor Crack width > 0.3mm to ≤ 1mm; 2 directions; Spacing ≥ 200mm to < 500mm		Cracks are caused by corroded rebar expansion inside concrete, especially reinforced concrete near sea shore.
	3. Bad Crack width > 1mm; 2 directions; Spacing < 200mm		This photograph shows typical cracks caused by sea water.
Spalling/ Disintegration	1. Fair Affected area > 150mm to ≤ 300mm wide in any direction or depth is > 25mm to ≤50mm		Rebars are exposed by spalling. This is typical spalling caused by sea water
	2. Poor Affected area > 300mm to ≤ 600mm wide in any direction or depth is > 50mm to ≤ 100mm		Spalling is caused by expansion of rebars corroded due to water leaking from expansion joint
	3. Bad Affected area > 600mm wide in any direction or depth is > 100mm		Spalling is caused by expansion of rebars corroded due to sea water

Table 3-7 Common Concrete Defects of Bridge Substructure (2/3)

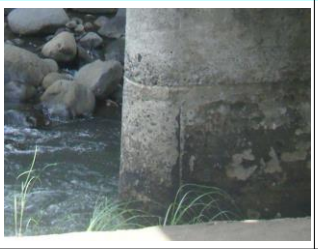
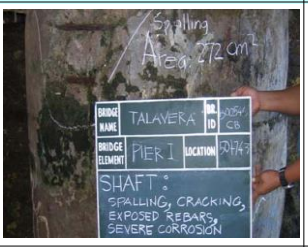
Defects	Conditions	Photography	Causes
Scaling	1. Fair Affected area > 150mm to ≤ 300mm wide in any direction or depth is > 25mm to ≤ 50mm		Concrete surface is deteriorating by local flaking or peeling-off of concrete or mortar near surface.
	2. Poor Affected area > 300mm to ≤ 600mm wide in any direction or depth is > 50mm to ≤ 100mm		Poor finishing practices result in weak layers at the top of concrete surfaces that easily peel-off by weathering or abrasion.
	3. Bad Affected area > 600mm wide in any direction or depth is > 100mm		Honeycomb occurred at the first stage. Scaling developed due to loss of fine aggregate together with the mortar.
Delamination	1. Fair Affected area > 150mm to ≤ 300mm wide in any direction		It is difficult to identify this condition visually. It can be detected by hollow sound when tapping the concrete surface with a rod or hammer.
	2. Poor Affected area > 300mm to ≤ 600mm wide in any direction		The major cause of delamination is the expansion of rebars resulting from corrosion.
	3. Bad Affected area > 600mm wide in any direction		If a patching repair is not made, concrete of the delaminated interface will eventually dislodge resulting to spalling.

Table 3-8 Common Concrete Defects of Bridge Substructure (3/3)

Defects	Conditions	Photography	Causes
Rebar Exposure/ Corrosion	1. Fair Width ≤ 50cm2		Rebars are exposed by spalling caused by impact due to drift woods.
	2. Poor 50cm2 < Width ≤ 100cm2		Rebars are exposed due to severe concrete spalling caused by expansion of corroded rebars.
	3. Bad 100cm2<Width and corroded		Rebars of pile bent are exposed by collision and abrasion on concrete due to strong river current.
	4. Bad 100cm2<Width & with Section Loss		Rebars of coping concrete were exposed due to severe spalling caused by expansion of the corroded rebars and then section loss of rebar has developed.
Honeycomb	1. Fair 150mm<Width ≤ 300mm in any direction		Honeycomb is caused by lack of mortar in the spaces between coarse aggregate caused by insufficient compaction during placement of concrete
	2. Poor 300mm < Width ≤ 600mm in any direction		The voids provide channels for water, and corrosive agents such as sea water that will eventually cause corrosion of steel reinforcement.
	3. Bad 600mm < Width in any direction	None	

3-1-5 Bridge Accessories

(1) Bearing

The common defects of bridge bearings are shown in Table 3-9.

Table 3-9 Common Defects of Bridge Bearings

Types of Bearing	Defects	Photography	Causes
Steel Bearing	1. Corrosion		Corrosion is the primary cause of section loss in steel members and is most commonly caused by the wet-dry cycles of exposed steel.
	2. Loose Connection		Loose connection of bearings can occur due to severe deterioration/ rusting of anchor bolts. This may cause the superstructure to fall off from from bridge seat.
	3. Abnormal Displacement		Abnormal movement of bearing occurs when anchor bolts are damaged or cut off.
	4. Paint Deterioration		Surface rusting can occur at pinholes in the paint, which are tiny, deep holes in the paint, exposing the steel. It can also be caused by thin paint coverage.
Rubber Bearing	1. Bulging		The full load of the superstructure is being applied to a smaller area on the bearing pad. This results in a higher stress that could crush the rubber bearing pad.
	2. Bed (Support) Damage		As concrete bearing seat is not provided, water leaking and debris buildup cause the girder and coping concrete to deteriorate severely.

(2) Expansion Joint

Common defects of bridge expansion joints are shown in Table 3-10.

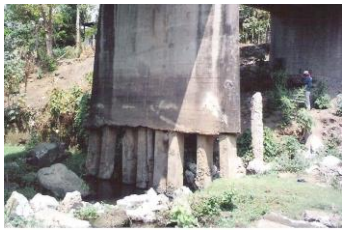
Table 3-10 Common Defects of Expansion Joints

Location	Defects	Photography	Causes
Sealant Joint, Steel Joint, Rubber Joint	1. Difference in Elevation		Difference in elevation is caused by girders fallen from bearing or depth of girder is reduced due to section loss of web plate.
	2. Deterioration of Sealant		The sealant joint is usually unprotected, when the edge of the deck is damaged, the sealant deteriorates and peels-off.
	3. Abnormal Space		Abnormal space occurred due to movement of expansion plates caused by the damaged anchor bolts which may be been cut off.
	4. Displacement		The top plate of sliding plate joint was displaced/damaged due to traffic impact and overloading.
	5. Water Leakage		Water leakage is caused by inadequate expansion joint which is not sealed by waterproof membrane.
	6. Rupture		Rubber expansion joint is often deteriorated by severe temperature and traffic impact.

3-1-6 Protection Works

The common defects of bridge protection works are shown in Table 3-11.

Table 3-11 Common Defects of Bridge Protection Works

Location	Defects	Photography	Causes
Abutment	1. Bank Erosion		Bank protection works made of stone masonry may be damaged during high floods
	2. Slope Erosion and Cracking		Stone masonry around abutment often collapse due to scouring or cracking on surface when masonry is not provided with appropriate concrete footing/anchorage.
	3. Material Loss /Scouring		Stone materials are missing from stone masonry and gabion mattress due to strong river flow.
Pier	1. Damage on Gabion Wire		Gabion damage is generally a woven mesh wire failure to be is flexible to ground movement. The wire failure is easily re-woven again for repair.
	2. Scouring		Concrete blocks around pier are damaged by local scouring which is caused by an imbalance between the input and output sediment transport rates around the pier.
	3. River Bed Degradation		Concrete piles are exposed above river bed. That means river bed degradation is occurred because natural river slope is steeper than the critical slope for degrading river bed.

3-2 PROCEDURE FOR SELECTING REPAIR METHOD

3-2-1 Selecting Repair Method

The repair methods suggested in this manual are prepared based on the condition rating criteria of the BMS. The different repair methods are selected according to the type of defects found on the bridge structure. The selection of repair methods however gives priority to bridges that will remain structurally sound after the repair and to those with defects which can be practically repaired, considering local conditions in the Philippines. For major repairs where the bridge exhibits different combinations of defects, corresponding repair measures shall be simultaneously carried out using the appropriate repair methods.

Prior to using this manual, the following should be considered to determine the appropriate repair method:

(1) Necessary Strength Based on Original Design

Repair methods included in this manual aim to maintain the capacity of the bridge based on its original design and not to further enhance its serviceability strength to meet the latest design requirements. Nevertheless, it is noted that even if the full design load capacity is achieved, slight overstressing due to the defect may be accepted for certain serviceability limits. Engineering judgment is also vital in selecting the appropriate repair method in order to minimize cost. For example, repair of the full flange area of a simply- supported steel girder may not be necessary near its end span since bending moment at this location is expected to be small.

(2) Bridge Service Life and Characteristic of Defects

The proposed repair methods are limited to realizing the corresponding repair costs, and not the value of the bridge's life cycle cost. Engineering inspection team of the DPWH need to also consider the following factors in determining the appropriate repair methods:

- The service life of steel bridges is governed by the fatigue life of a steel section. It is not practical to spend largely on repairs if the bridge is close to its predicted fatigue life (50~60 years in Philippines), hence, replacement is a better option.
- In concrete structures, defects such as corrosion of reinforcement may not be visible. However, such defects are known to occur in the form of concrete cracking or spalling.
- It is not practical to spend on repairs for some localized defects if more extensive defects are expected to appear in the near future. For such case, engineering inspection should be conducted for the complete structure prior to implementation of costly repairs of local concrete defects.

(3) Detailed Evaluation/Assessment in Engineering Inspection

This manual does not provide assessment of the cost of repairs against its possible benefits, which could be the basis in deciding between repair and reconstruction. It should be noted that reconstruction is not covered in this manual. However, an engineering assessment for the necessity of reconstruction should also be undertaken by the engineering inspection team.

(4) Partial Replacement of Bridge

In case a primary bridge component exhibit defects that appear to spread widely and have continuously progressed, partial replacement of the component could be considered. This may involve replacement of damaged bracing members, stiffeners, stringers, cross girders, but not to the extent of completely replacing the components. (Total replacement of girder or deck slab is not included in this repair manual.)

(5) Total Repair Cost for Defects

The repair costs refer to the unit cost of each repair. The total cost for implementing repair should also include the following items for each bridge, with due consideration of the scale and location (terrain) of the bridge in concern:

- Transportation cost of materials and equipment
- Scaffolding, staging and other temporary facilities
- Detour road or detour bridge if necessary
- Management cost (Overhead and profit)

(6) Adverse Problems on the Structure and Traffic

Consider the following issues that may cause adverse problems during the implementation of the bridge Repair:

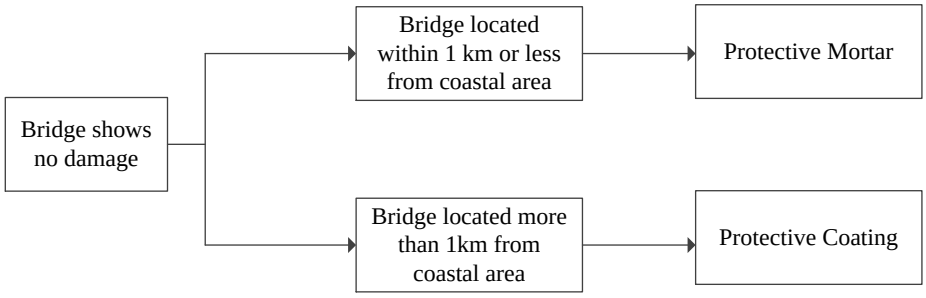
- Detour road or bridge for rerouting traffic flow.
- Reduction of traffic load clearances during overlay or jacking-up of girder
- Structure becomes more vulnerable to damage or deterioration during repairing
- Other potential defects observed

3-2-2 Preventive Maintenance

Although a bridge may not have any damage, it is recommended that the bridge members be protected from effects of carbonation and salt attack.

If the bridge is located more than one (1) kilometer from coastal area, protective coating made of acryl urethane based coating is applied to protect the bridge not only from carbonation but from weather/UV rays, chemical and oil damage. Refer to Sections 4-10, 5-8, and 6-6 for details of application of protective coating.

If the bridge is located less than one (1) kilometer from coastal area, protective mortar is applied to protect the bridge from effects of salt attack. Protective mortar is made from lithium nitrate polymer cement mortar. Refer to Sections 4-9, 5-7, and 6-5 for details of application of protective mortar



3-2-3 Cracking on Concrete Structure

Generally, fine and stable cracks with up to 0.3 mm width have no adverse effect if concrete cover to reinforcement is adequate. These cracks are generally harmless and need not be repaired.

Defective cracks with over 0.3 mm width develop due to carbonation, chlorination, alkali aggregate reaction, rebar corrosion, overloading of structure, foundation movement, and lack of adequate cover. It is important to identify the presence of these causes. All defective cracks must be repaired as shown in Figure 3-1 to Figure 3-3. The repair methods for cracks are classified according to crack width, based on the Condition Rating Criteria of the BMS.

(1) Deck Slab

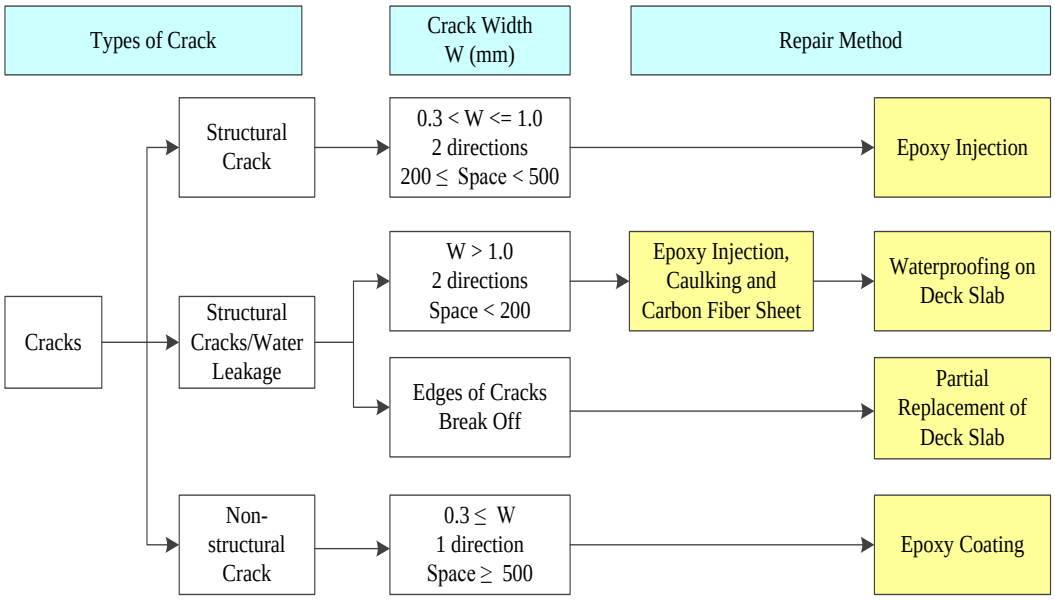


Figure 3-1 Selection Procedure of Repair Method for Deck Slab Due to Cracks

(2) Superstructure

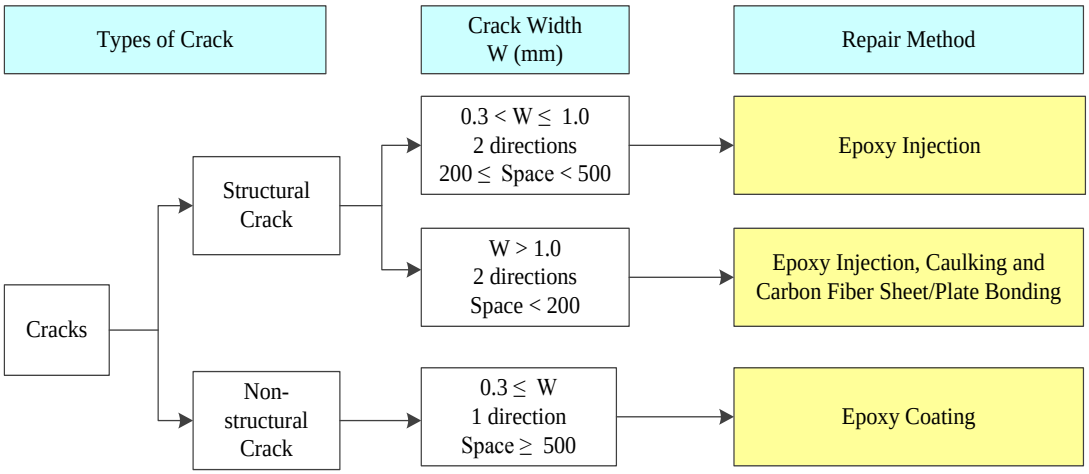
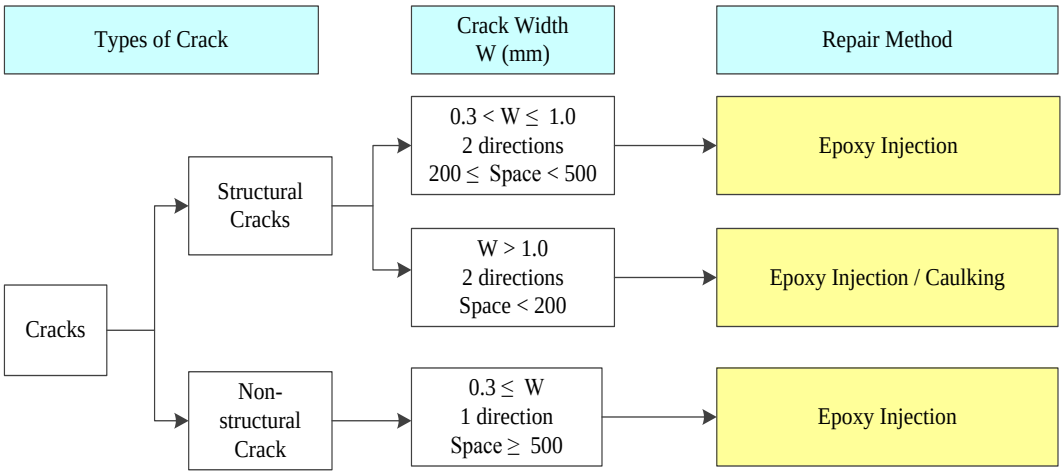


Figure 3-2 Selection Procedure of Repair Method for Girder Due to Cracks

(3) Substructure



Remark: Epoxy injection repair shall be similar to the epoxy injection for superstructure.

Figure 3-3 Selection Procedure of Repair Method for Substructure Due to Cracks

3-2-4 Spalling, Scaling and Disintegration on the Concrete Structure

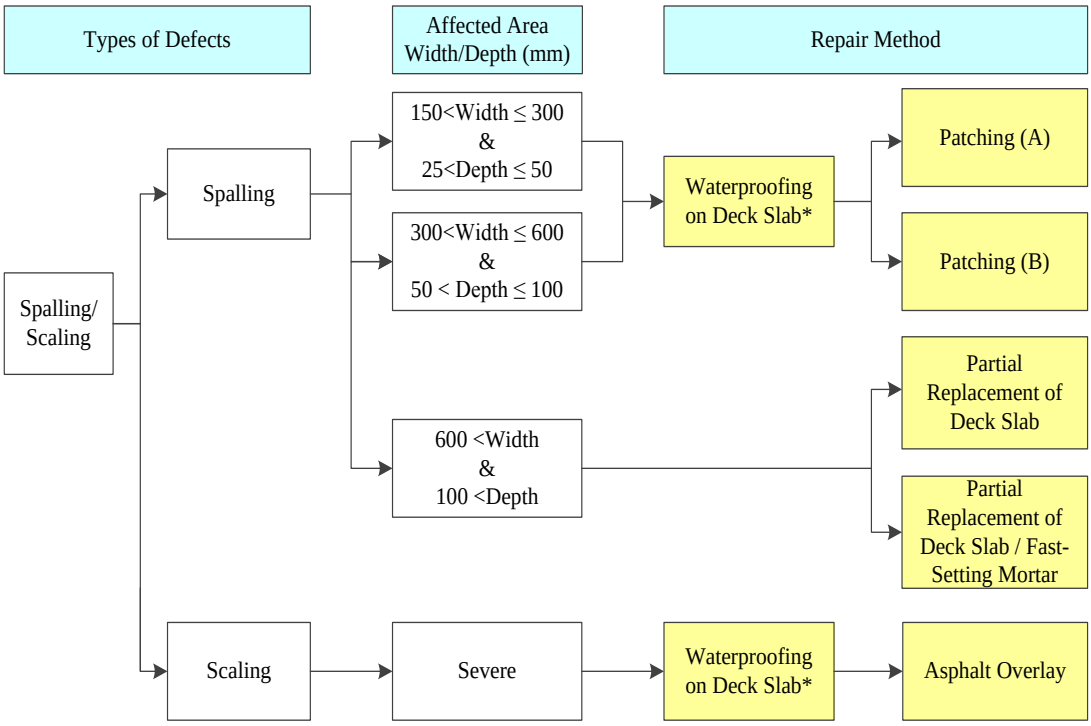
Spalling is defined as a depression resulting from detachment of a large fragment of concrete. On the other hand, disintegration is a depression resulting from detachment of small fragment. The major cause of spalling is expansion resulting from corrosion of reinforcement. Spalling caused by impact can weaken the structure locally and expose the reinforcement to corrosion.

Scaling of concrete surfaces is defined as local flaking or peeling away of concrete near the surface. As the deterioration continues, coarse aggregate particles are exposed and eventually become loose.

All defects must be repaired based on the flowchart shown in Figure 3-4 to Remark*: For pile bents, repair method is applied with concrete jacket

Figure 3-6. The repair method for spalling is classified according to width and depth damaged, while that for scaling is only according to the width of damage on the concrete. This is based on the Condition Rating Criteria of the BMS.

(1) Deck Slab



Remark*: Waterproofing shall be conducted after repair of damaged areas

Figure 3-4 Selection Procedure of Repair Method for Deck Slab due to Spalling and Scaling

(2) Superstructure

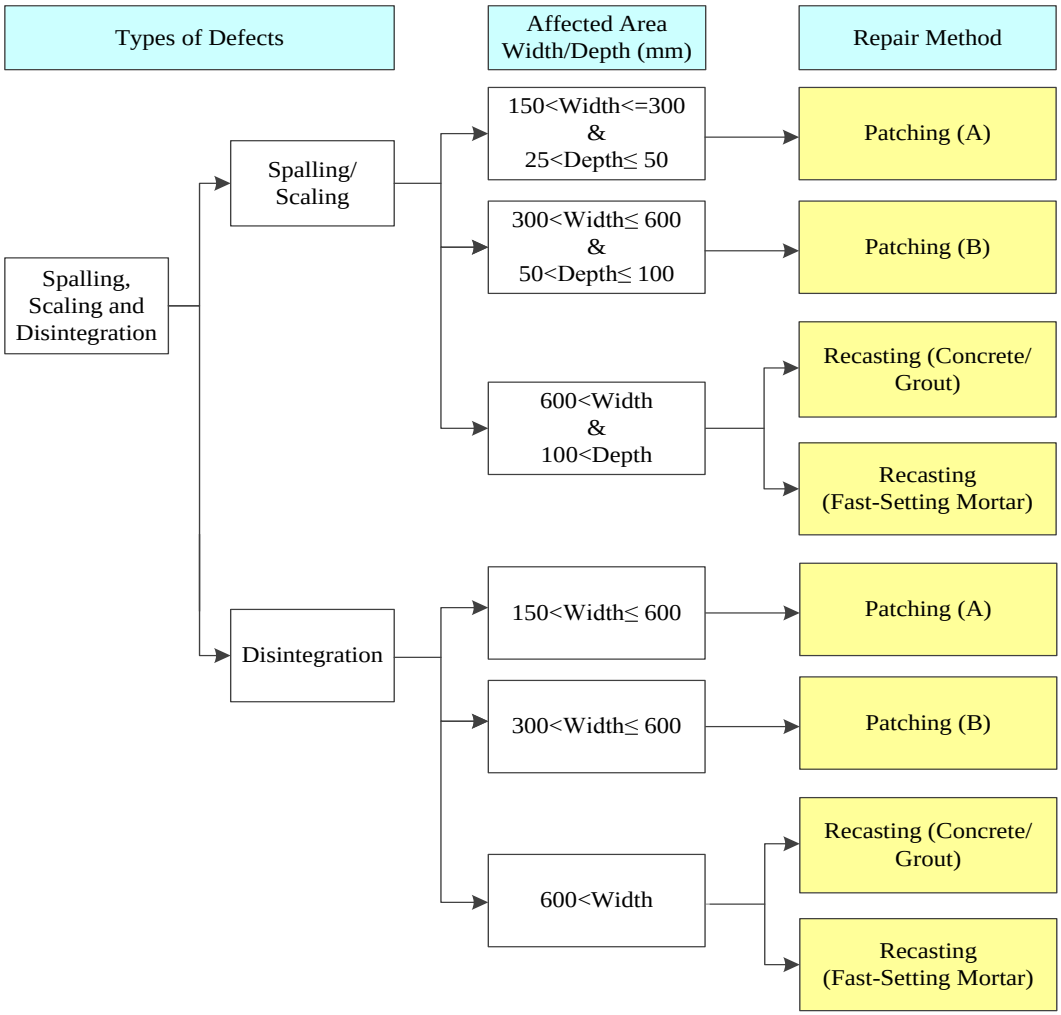
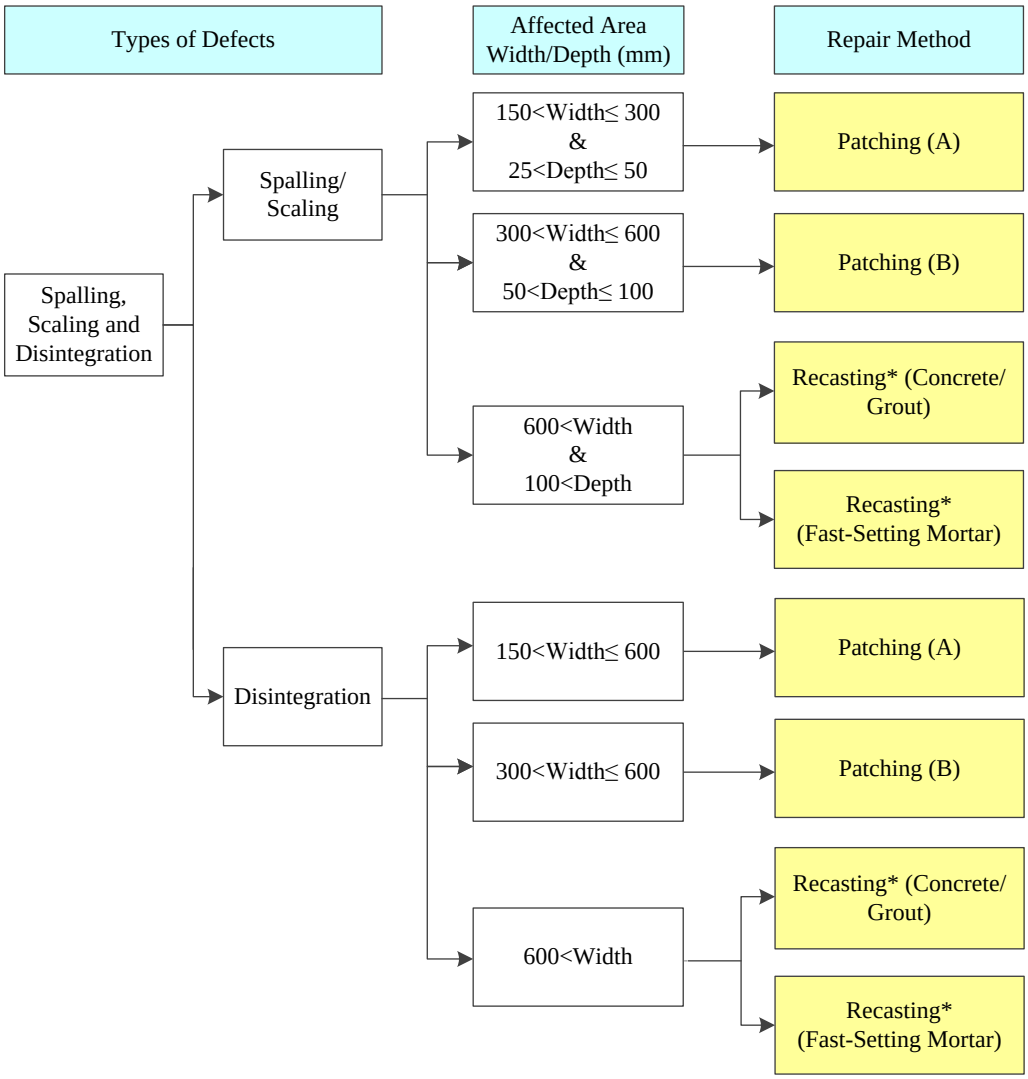


Figure 3-5 Selection Procedure of Repair Method for Superstructure Due to Spalling, Scaling and Disintegration

(3) Substructure



Remark*: For pile bents, repair method is applied with concrete jacket

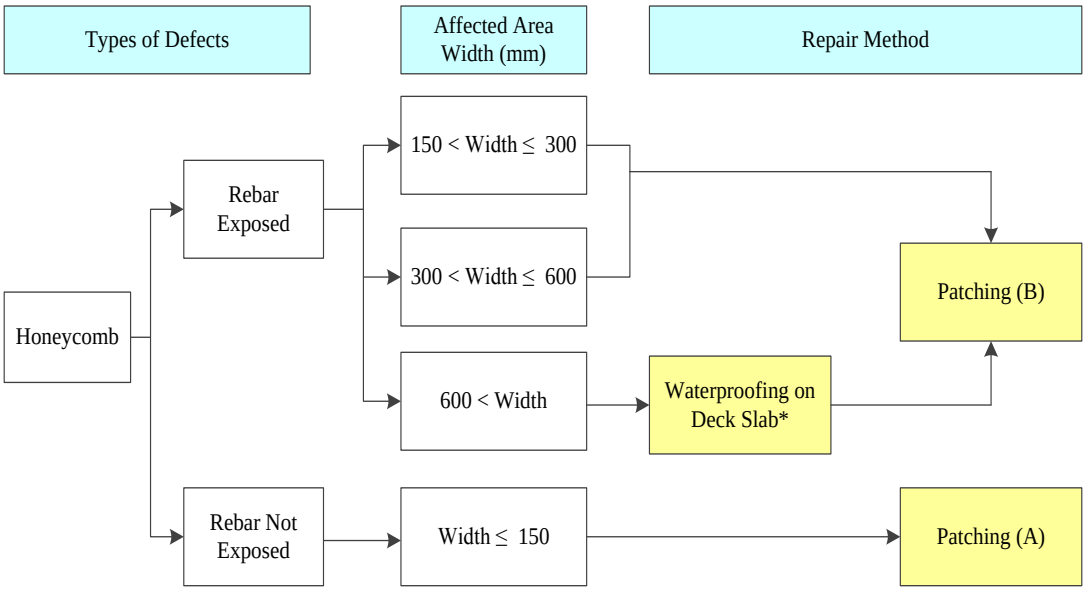
Figure 3-6 Selection Procedure of Repair Method for Substructure due to Spalling, Scaling and Disintegration

3-2-5 Honeycomb on Concrete Structure

Honeycomb is formed due to lack of mortar in the spaces between coarse aggregate particles. It is caused by insufficient compaction or vibration during the placement of concrete, resulting in a porous and weak reinforced concrete. The voids will allow ingress of water, oxygen and corrosive agents such as carbon dioxide, chlorides and sulfates that will eventually cause corrosion of the steel reinforcement.

Honeycomb defects must be repaired based on the flowcharts shown in Figure 3-7 to Figure 3-9.

(1) Deck Slab



* Water proofing shall be applied after deck repair

Figure 3-7 Selection Procedure of Repair Method for Deck Slab Due to Honeycomb

(2) Superstructure

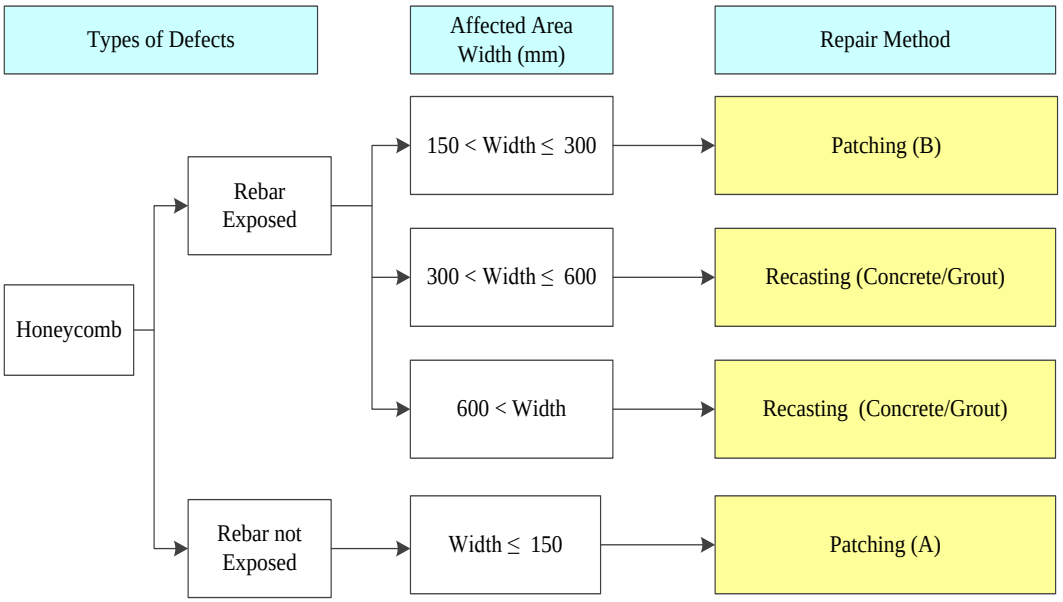


Figure 3-8 Selection Procedure of Repair Method for Superstructure Due to Honeycomb

(3) Substructure

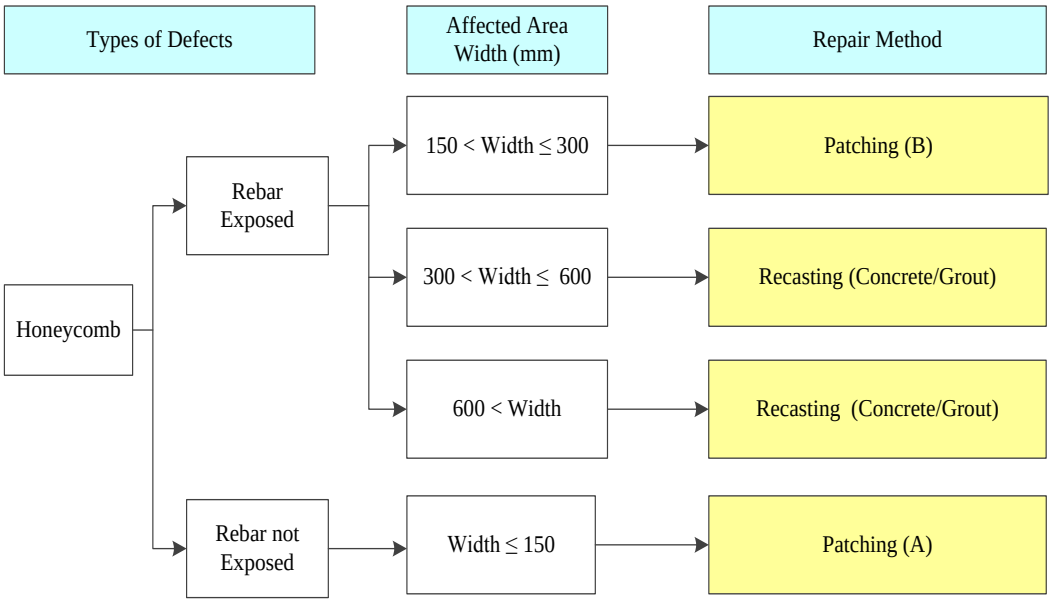


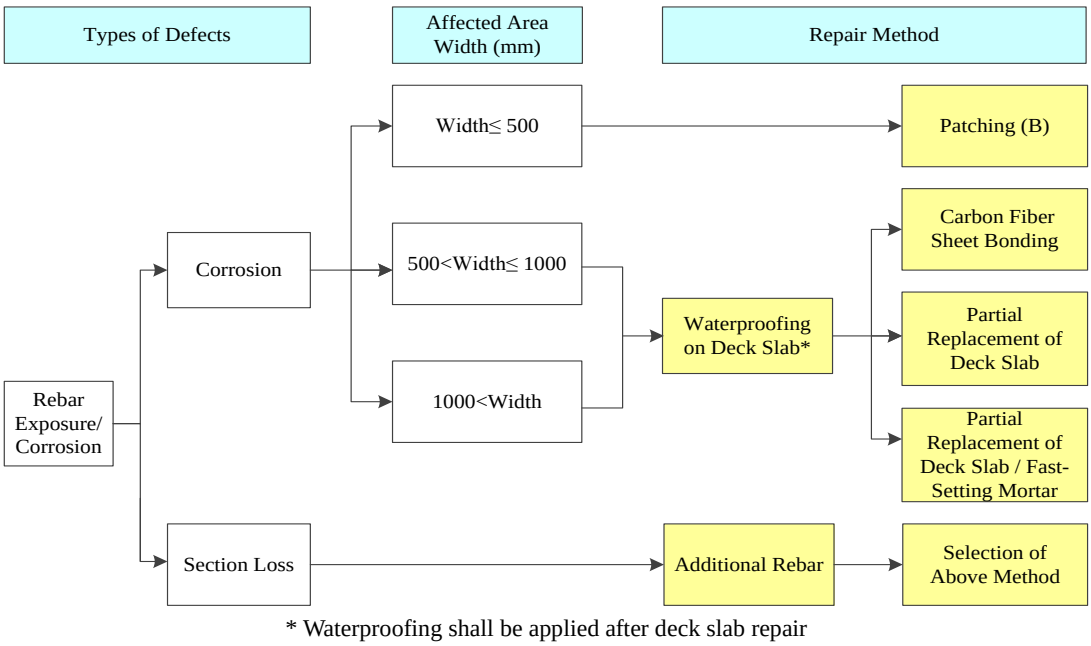
Figure 3-9 Selection Procedure of Repair Method for Substructure Due to Honeycomb

3-2-6 Rebar Exposure on Concrete Structure

During initial occurrence of defects such as spalling, scaling and delamination, exposure of rebars to air are limited, hence, does not significantly affect the strength and serviceability of the bridge structure. In severe cases where rebars are widely exposed and loss of section seem progressive strength and serviceability of the bridge is consequently reduced.

All defects must be repaired based on the flowchart shown in Figure 3-10 to Figure 3-12. The applicable repair method for rebar exposure is determined according to the width of defective area on the concrete.

(1) Deck Slab



* Waterproofing shall be applied after deck slab repair

Figure 3-10 Selection Procedure of Repair Method for Deck Slab Due to Rebar Exposure

(2) Superstructure

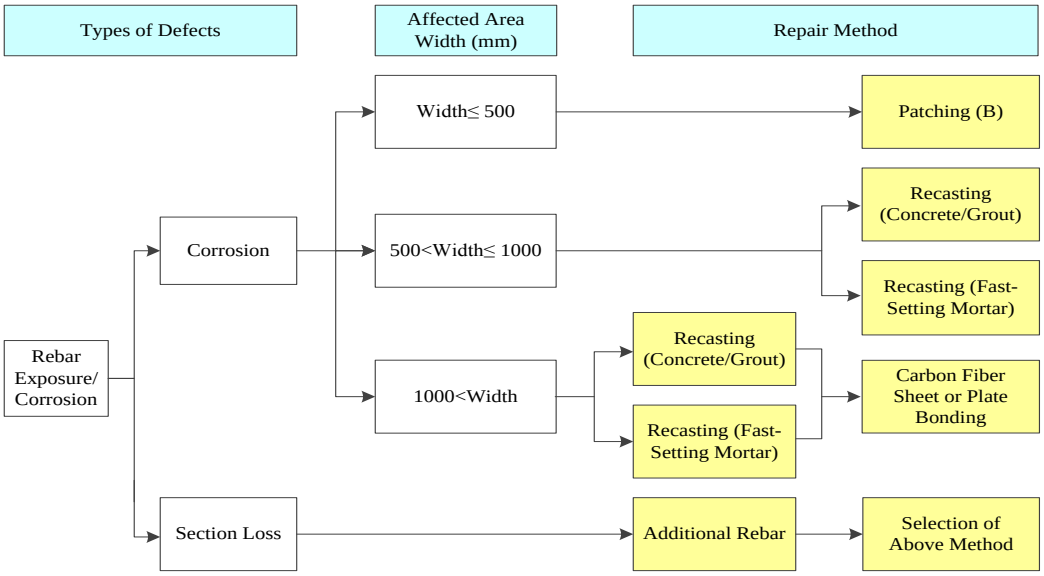
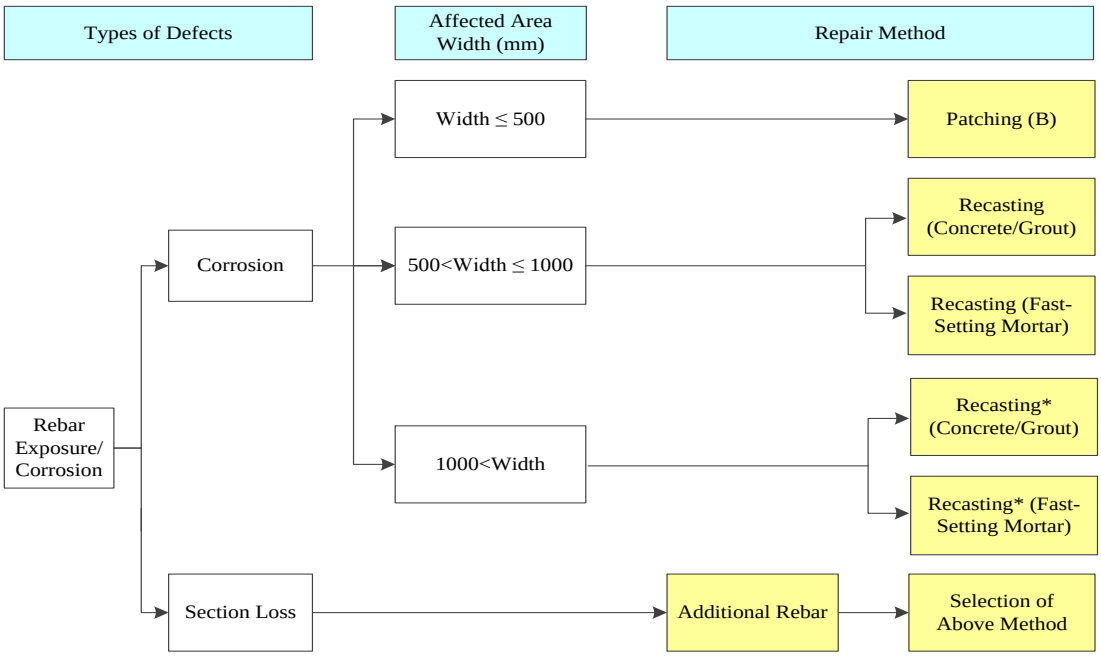


Figure 3-11 Selection Procedure of Repair Method for Superstructure Due to Rebar Exposure

(3) Substructure



*For pile bent, repair is by application of concrete jacket

Figure 3-12 Selection Procedure of Repair Method for Substructure Due to Rebar Exposure

3-2-7 Delamination on Concrete Structure

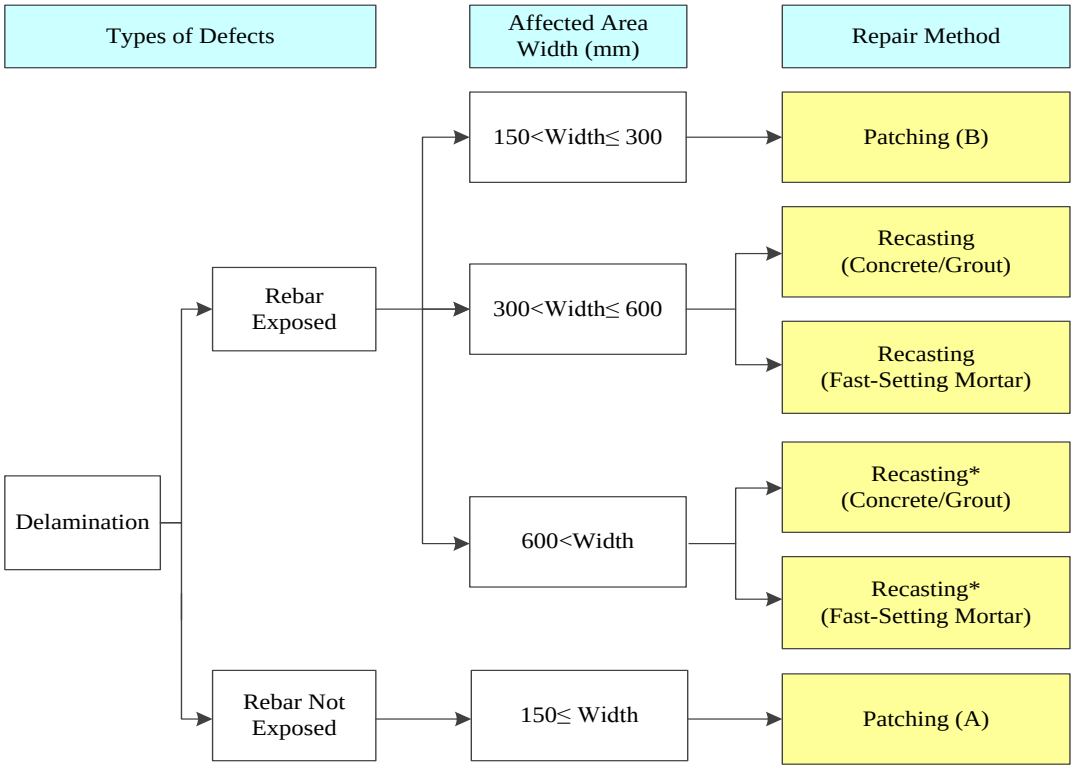
Delamination is the separation of concrete from the reinforcing steel. Delamination may not be identified visually since the defect is beneath the concrete surface. Sound tapping on the surface allows accurate identification of the affected area on the concrete surface. To confirm the delaminated

areas, hammer shall be used to break the inspected surface. It should be realized that if the corresponding repair is not successful, the concrete will eventually spall off.

All defects must be repaired based on the flowchart shown in Remark: If there is section loss of rebar, repair method with mark * is applied with carbon fiber sheet/plate bonding after recasting

Figure 3-13 and Figure 3-14.

(1) Superstructure



Remark: If there is section loss of rebar, repair method with mark * is applied with carbon fiber sheet/plate bonding after recasting

Figure 3-13 Selection Procedure of Repair Method for Delamination in Superstructure

(2) Substructure

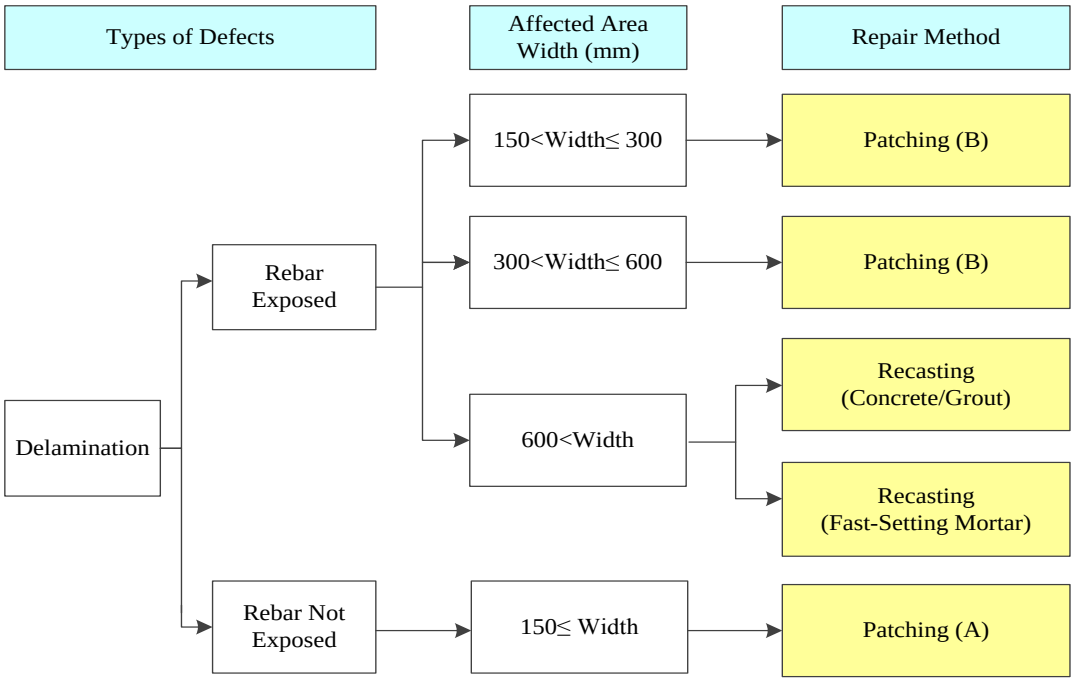


Figure 3-14 Selection Procedure of Repair Method for Delamination in Substructure

3-2-8 Corrosion on Steel Structure

Repainting may be the only repair measure required against rusting and corrosion of steel members. It may also be implemented to supplement other repair measures for strengthening section loss. The most effective method against corrosion is to apply abrasive blast cleaning prior to the proper application of a high quality paint system and touch-up painting as routine maintenance. Heavy corrosion with section loss often appears at the end of lower flanges, thus, special anti-corrosion paint should be applied to avoid progressive corrosion. The repair method for rust/corrosion is classified according to the severity of the condition and the percentage of section loss, based on the Condition Rating Criteria in BMS.

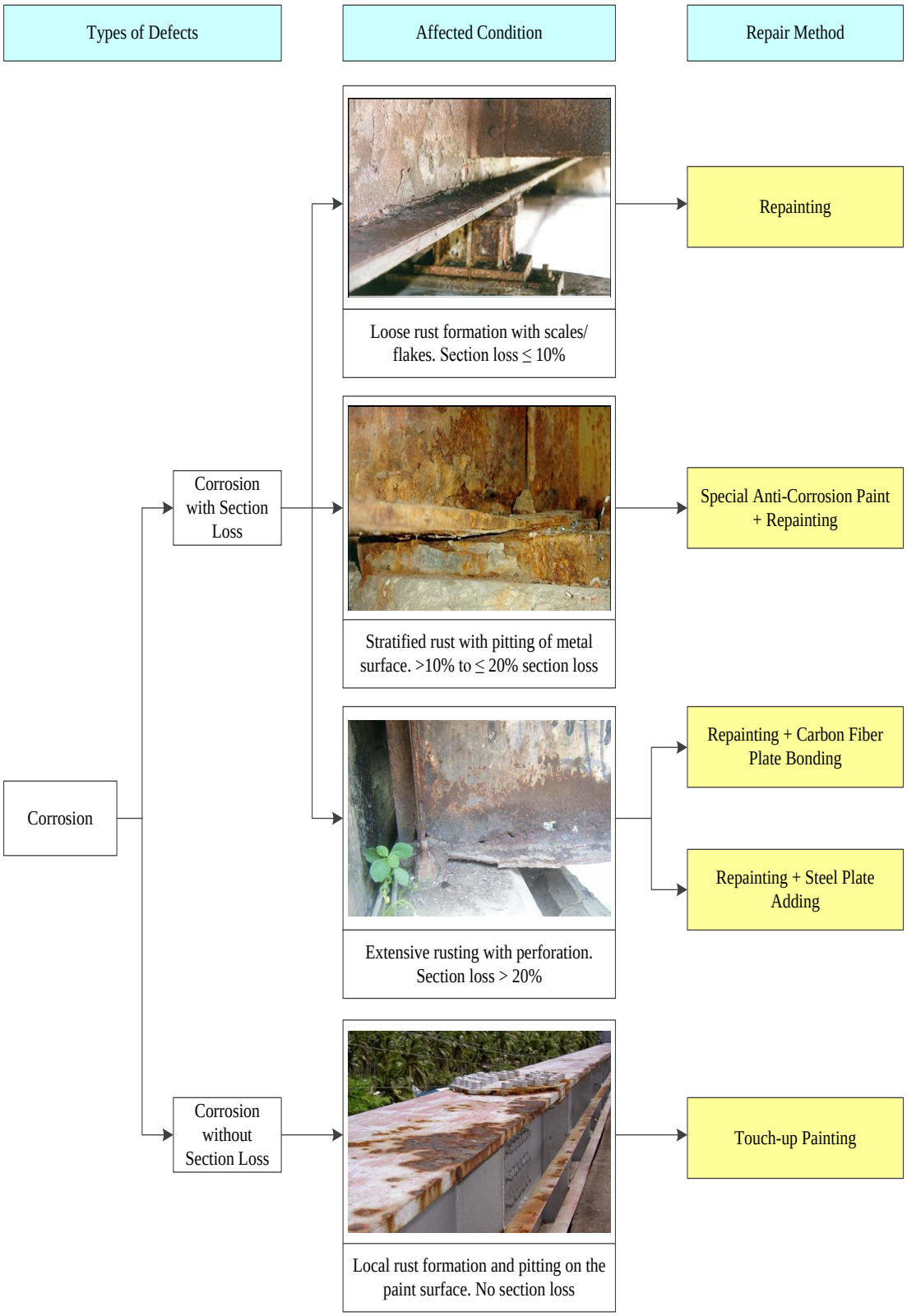


Figure 3-15 Selection Procedure of Repair Method for Steel Due to Corrosion

3-2-9 Paint Peel-off of Steel Structure

Paint peel-off on steel bridges is commonly found on bridges constructed in the 1980's. Touch-up painting is initially required to supplement the repainting repair for corrosion protection. This shall be applied to the steel structure, prior to final application of paint coating intended to restore the uniform appearance of the bridge. The repair method for paint peel-off is classified according to the percentage of affected surface area, based on the Condition Rating Criteria in BMS.

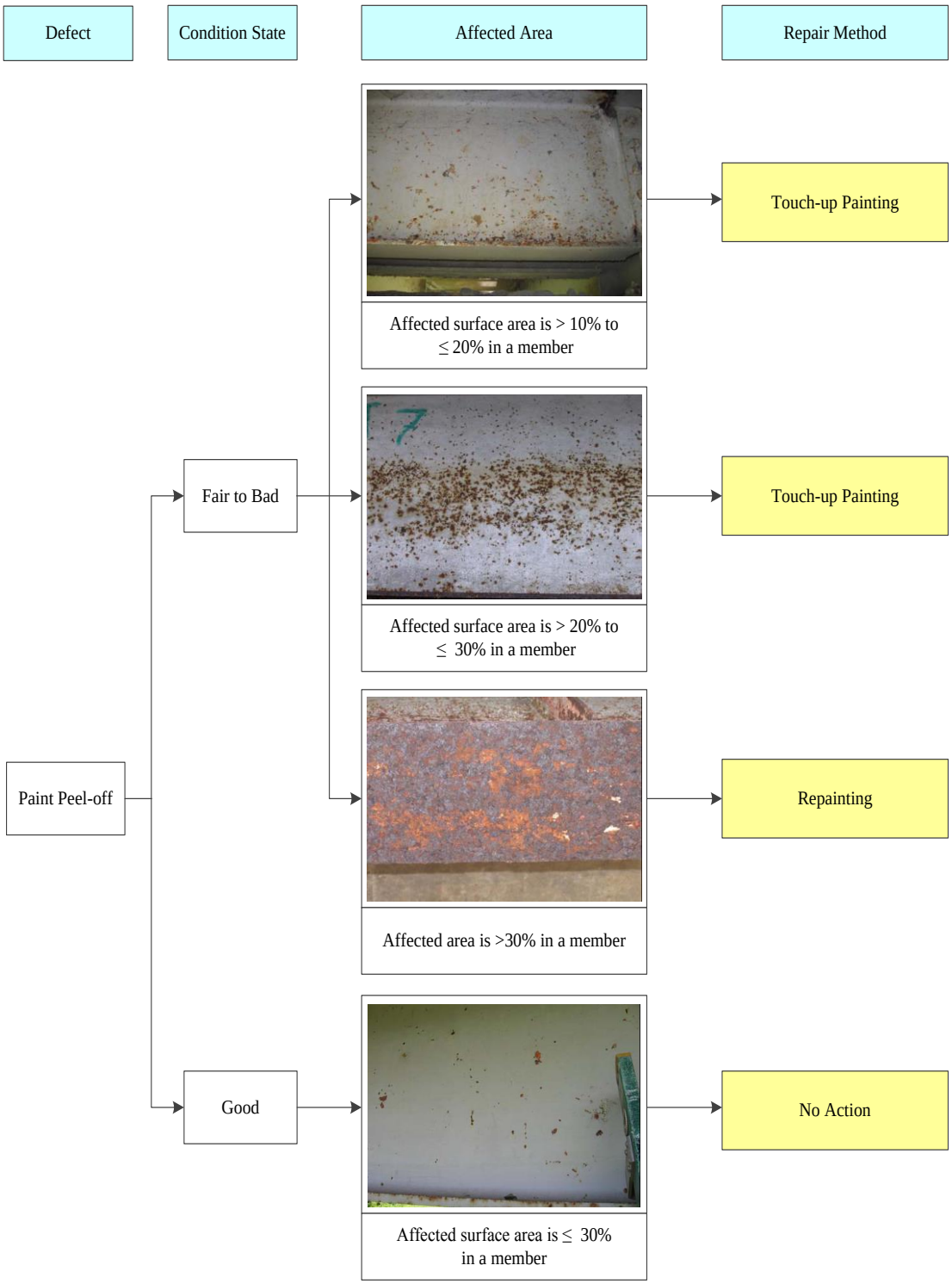


Figure 3-16 Selection Procedure of Repair Method for Steel due to Paint Peel-off

3-2-10 Loose Bolt Connection

Bolts at joints connecting the steel members are sometimes loosened or missing. There were cases where these are merely replaced with ordinary bolts instead of High Tension Bolts (HTB) or steel fasteners. Such conditions subject the bridge to risk of collapse. Repair for loose bolt connection is by resetting or retightening of HTB. The repair method for this defect is classified according to the percentage of loose fasteners and numbers of bolts that fell off from its connection, based on the Condition Rating Criteria in BMS.

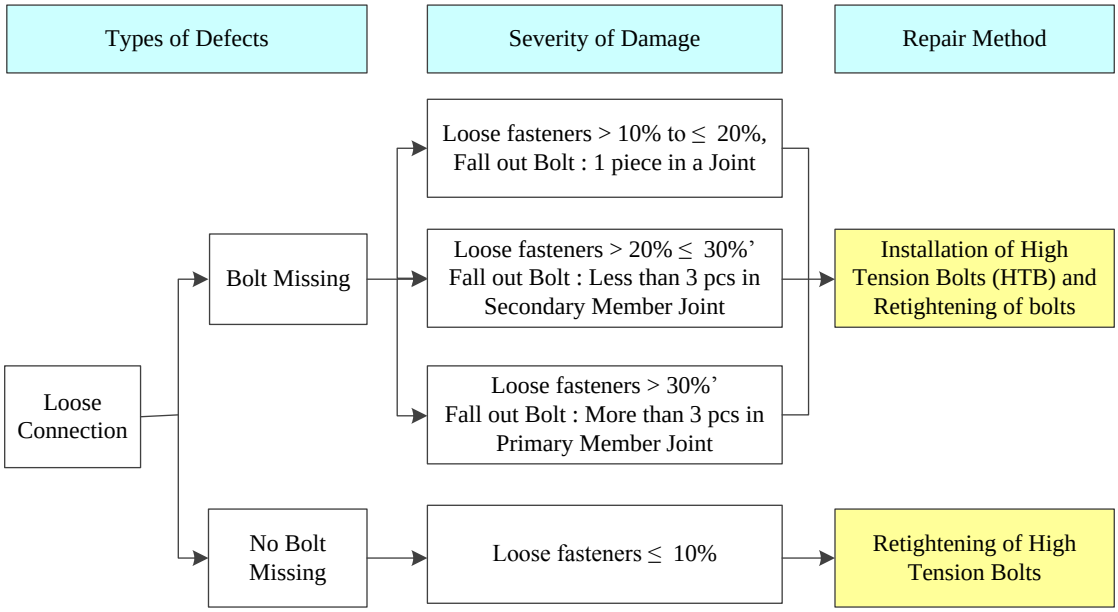


Figure 3-17 Selection Procedure of Repair Method for Steel Due to Loose Bolt Connection

3-2-11 Repair of Bridge Accessories

(1) Expansion Joint

The three major types of expansion joints used for bridges in the country include sealant, rubber and steel joints. These are often damaged because of rain water leakage. Said leakage causes many other damages on the bridge such as degradation of bearings and corrosion of steel girder. Damaged expansion joint should be replaced with seamless joint or a new type of rubber and steel joint with under drain function. The repair method for expansion joint is classified according to the extent of the damage, based on the Condition Rating Criteria in BMS.

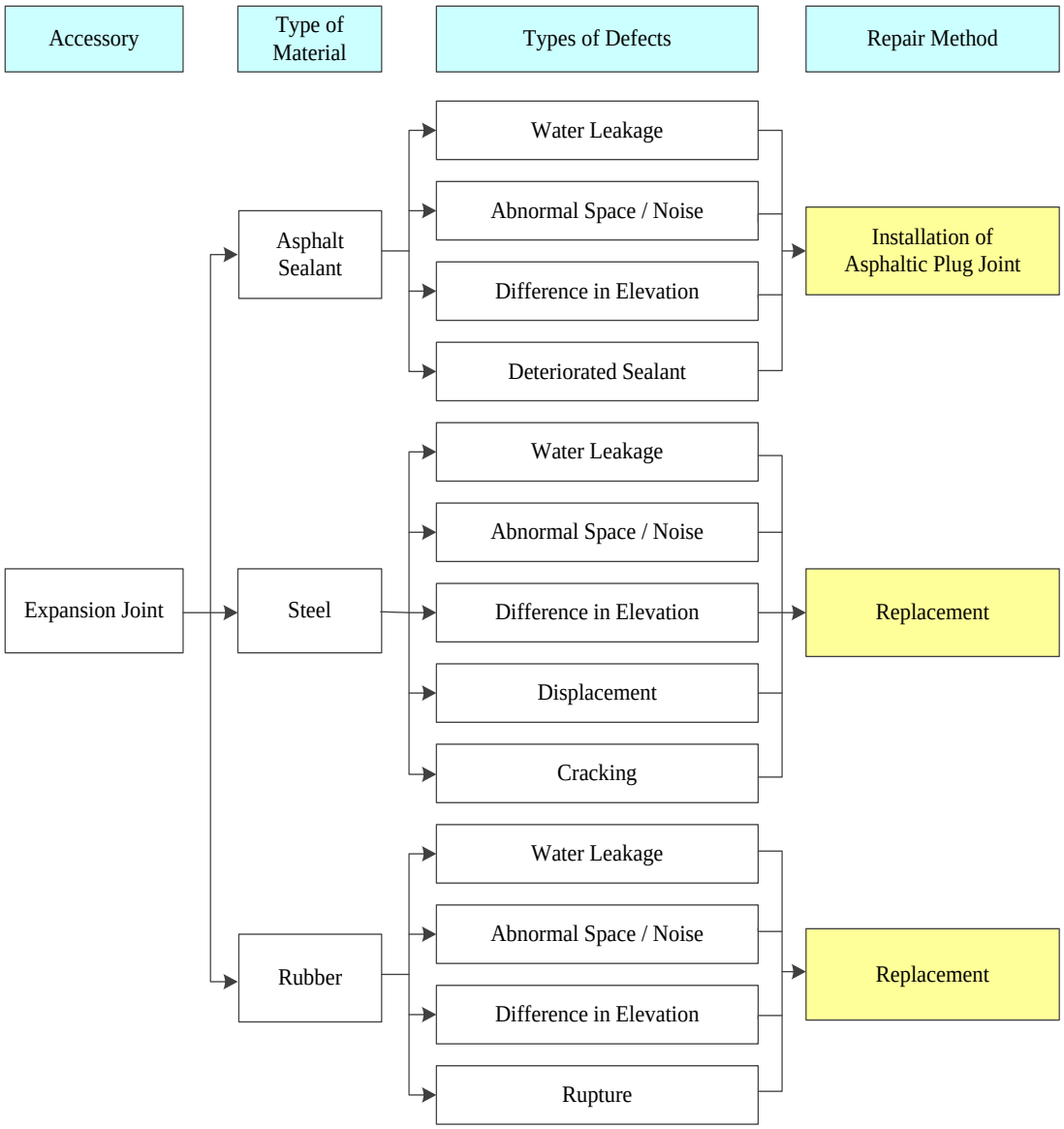


Figure 3-18 Selection Procedure of Repair Method for Expansion Joints

(2) Bearings

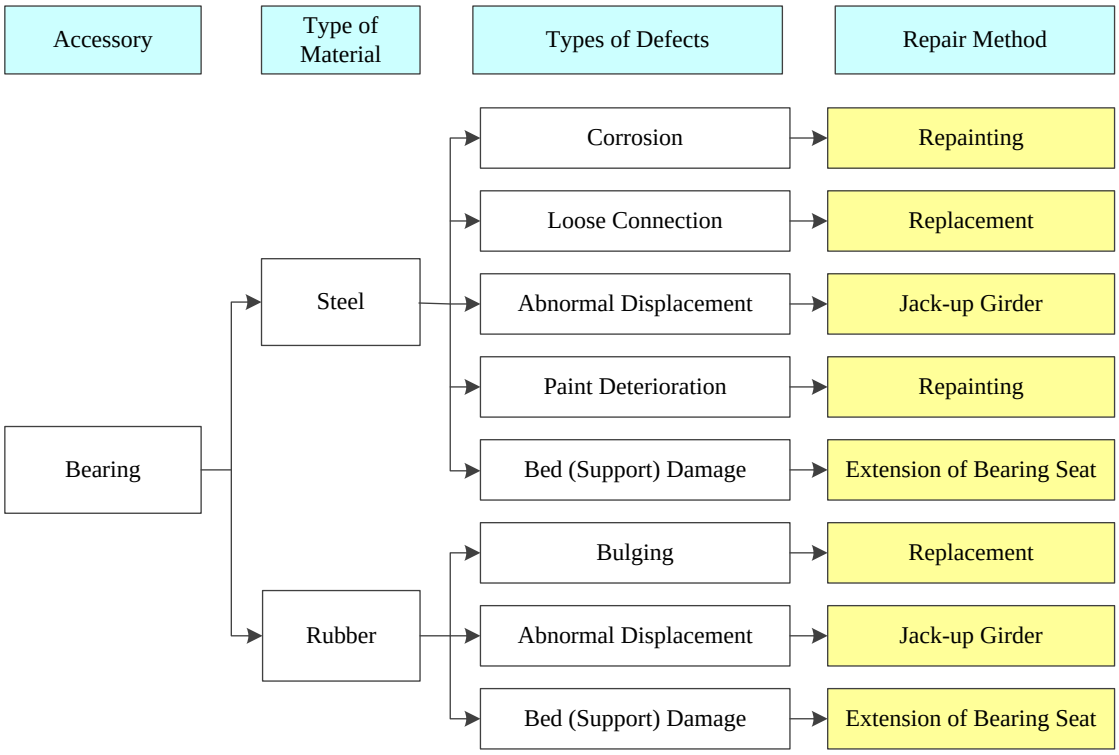
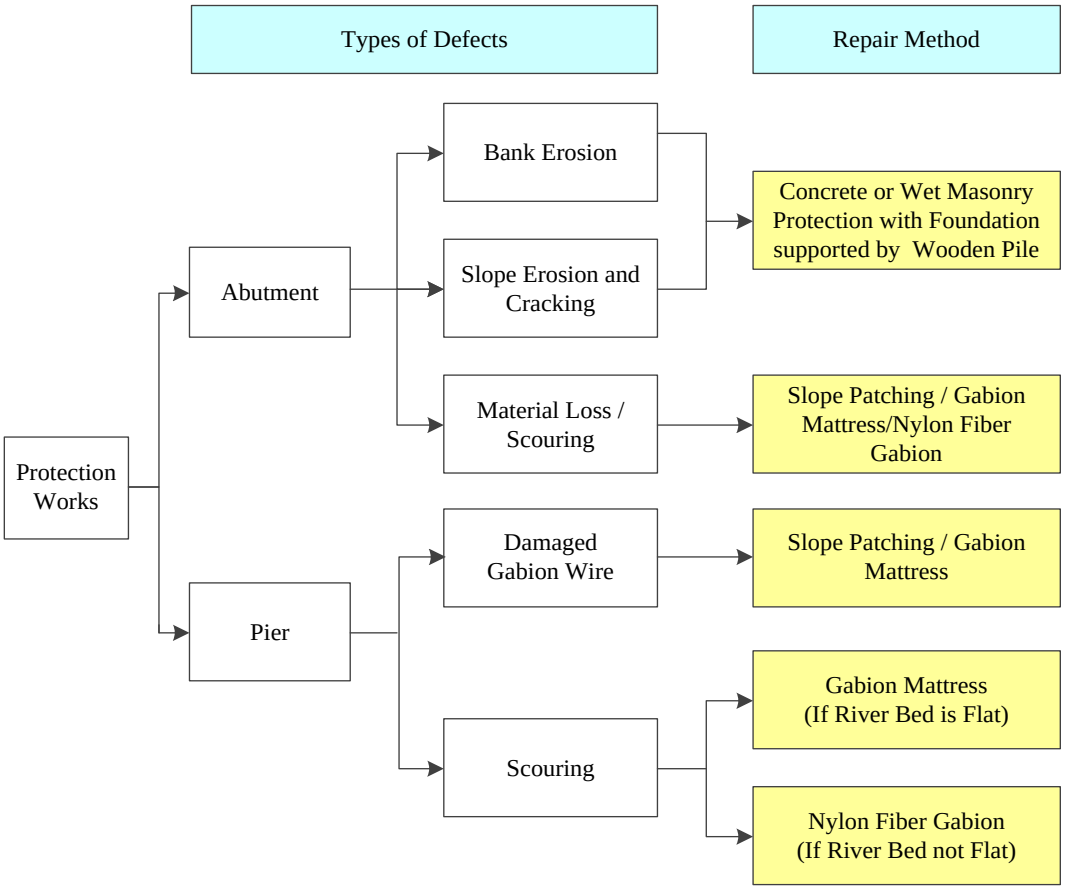


Figure 3-19 Selection Procedure of Repair Method for Bearings

3-2-12 Protection Works



Note: Each damage ranked with "Bad" in Condition of Rating Criteria will be repaired based on recommended Repair Method.

Figure 3-20 Selection Procedure of Repair Method for Protection Works

3-3 MAJOR MAINTENANCE ACTIVITIES

3-3-1 Concrete Repair Activities

The most important consideration in repairing any structure is to ensure adequate strength and stability of the bridge at all times. This is particularly relevant for repairs to reinforced concrete elements, where significant areas of concrete are to be removed or to be subject to repair. In such cases the strength or stability of the structure where a portion of concrete is removed should be checked by a structural engineer, before commencing appropriate repairs. Moreover during repair activities, load restrictions should be imposed and the structure temporarily supported as necessary.

In repair of concrete structures knowledge on the following is essential prior to implementation of related activities:

1) Types of defects which can occur due to deterioration, e.g. cracks, spalls, delamination, scaling, honeycombing etc.,
2) Causes of cracks such as chloride penetration, carbonation, alkali - aggregate reaction, shrinkage and thermal effects, foundation movements etc.,
3) Test methods for assessing the severity of deterioration.
4) Selection of appropriate repair materials, from ordinary Portland cement to synthetic polymers, epoxy resins and carbon fiber sheet/plate according to particular requirements of a repair method,
5) Selection of appropriate repair procedure

The details for items 1) and 2) were discussed in the previous sections, while items 3) to 5) will be covered in Chapter 5. However, these exclude complex and advanced repair methods (except for carbon fiber sheet/plate bonding and waterproofing on the deck) as this manual is intended only for structures that will remain structurally sound after the repair and to those with defects which can be practically repaired, considering local conditions in the Philippines.

Furthermore, the repair methods are suitable only to reinforced and plain concrete, and not to prestressed concrete.

3-3-2 Steel Repair Activities

Activity on steel repair mainly involves repainting for rusted and corroded steel structures, and touch-up painting as part of routine maintenance.

Regarding defects concerning section loss in steel bridges, which resulted from heavy corrosion, it is evident that its original condition cannot be reinstated. Similarly, restoring physically damaged steel to its original condition is often difficult. Corresponding repairs therefore involve fitting new steel or carbon plates to compensate for the section loss, in order to restore original strength and serviceability.

The two standard methods for connecting new steel plates are welding and mechanical fastenings (bolts, etc.). Among these, mechanical fastenings exhibit the least potential problems, although welding is usually more convenient and less costly.

The two main potential problems with field welded connections are as follows:

1) Satisfactory welds may be difficult or impossible to achieve for steel of older bridges due to their metallurgical properties; and
2) Fatigue life of the structure may be adversely affected by welding.

Considering these, mechanical fastening (HTB) should be adopted as the standard repair method.

3-3-3 Bridge Accessory Repair Activities

3-3-3-1 Expansion Joint

Deck slab for RCDG Bridge is commonly provided with a joint sealant between the bridge deck and abutment, and at gaps above intermediate supports (in case of multiple span superstructure). The damaged joint sealant, usually unprotected, allows water and debris to pass through the joint. As a result, debris is accumulated around the bearings on top of abutments and piers. Consequently, the leaking water becomes contaminated and damped to the river under the bridge. This eventually has adverse effect to the environment. Corrosion meanwhile could accelerate on the provided steel bearings. Such joints should therefore be replaced with a seamless type, as shown in Figure 3-21. This is suitable in the Philippines considering elongation and shrinkage due to temperature is not significant.

Deck slabs for steel and PCDG bridges are commonly provided with a sliding plate joints, as shown in Figure 3-22. The usual damage occurring on the sliding plate joint, involves missing cover plate due to detached set bolts. The resulting situation is then similar to that described above for damaged joint sealant. Simultaneous to application of new waterproofing and asphalt overlay to the damaged deck slab, expansion joints should be replaced with a rubber or steel expansion joint.

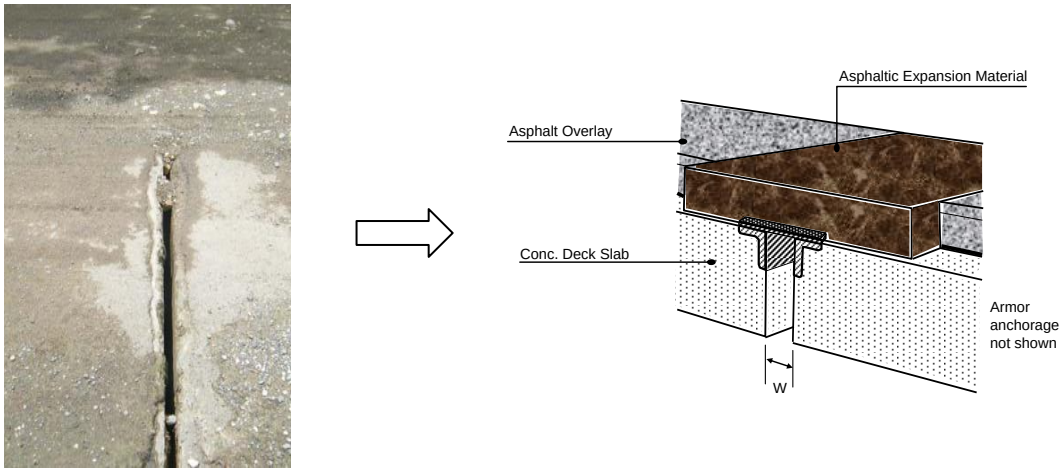
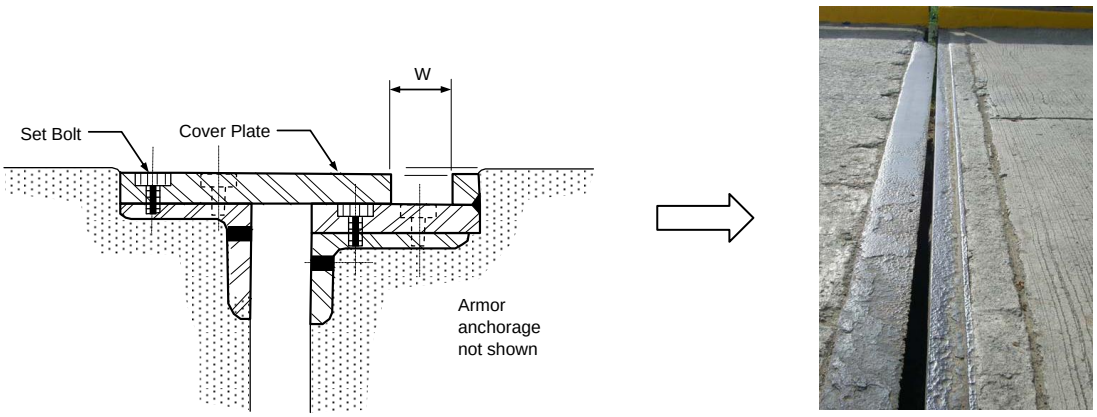


Figure 3-21 Asphaltic Plug Joint



(Original) (After Removal of Cover Plate)

Figure 3-22 Sliding Plate Type Expansion Joint

3-3-3-2 Bridge Drainage

Deck slab drains in most bridges are not efficiently functioning due to lack of drain pit and small drain pipe size, causing it to clog. This will eventually cause standing rain water to remain on the deck for some time. This rain water will then cause deterioration of the deck slab. Therefore, these clogging pipes shall be replaced with large PVC drain pipes, fitted into gently sloped drain pits.

3-3-3-3 Bridge Bearing

RCDG bridges were commonly found not supported with bearings and are placed directly on top of abutment and pier coping. This cause damage to the bottom portion of the girder ends, considering that the superstructure is subjected to traffic impact and thermal movement of the concrete girder. For arterial and main roads where heavy traffic occurs frequently, bridge bearings are necessary to ease traffic impact and to allow for movement without overstressing the concrete girder.

Meanwhile, steel girder and truss bridges are commonly supported by steel sliding bearings and rocker bearings, respectively. Both types of steel bearing were usually observed to be heavily corroded and no longer functioning. For short span steel bridges, rubber bearings as shown in Figure 3-23, may be suitable in the Philippine's considering its weather conditions such as slight temperature differences and rainfall occurrences.

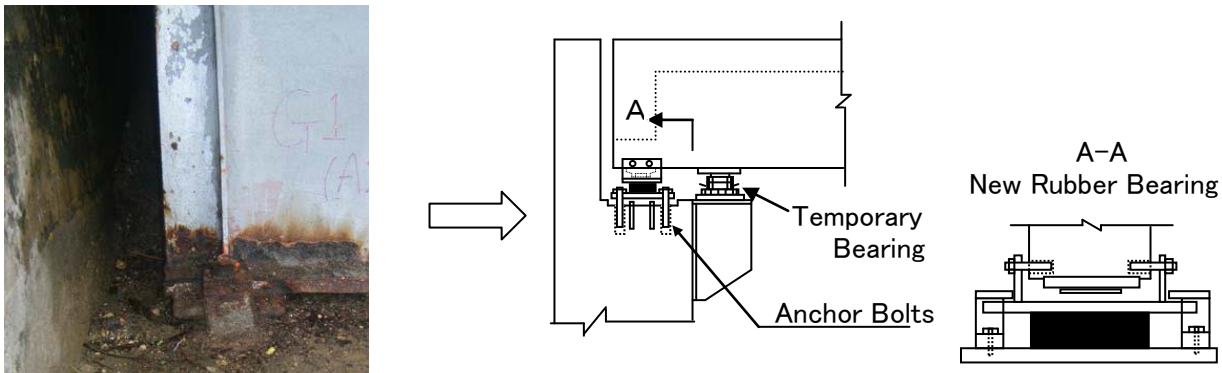


Figure 3-23 Replacement of Bearing

3-3-4 Protection Works Activities

3-3-4-1 Slope Protection/Bank Erosion

Most slope protection at riverside and around abutments are made up of stone pitch filled with mortar along the slope. The slope protection is not commonly supported on footing, thus, sliding and settlement of the slope occur due to local scouring at its toe. At places where slope protection is severely damaged, durable alternative such as concrete or wet masonry protection with footing supported on piles is necessary as repair measure. Concrete protection is more costly than the other methods. Types of abutment protections are determined based on the following:

1) Concrete protections are considered where water velocity is high;
2) Wet masonry is usually considered as abutment protection and at other sections;
3) Gabions are provided where settlement and deformation of riverside protection occur
4) Gabions are also considered between the unprotected riverside and the protected riverside (wet masonry or concrete).

3-3-4-2 Local Scouring

Local scouring occurs around piers and toe of abutments due to high river flow velocity. According to survey results on hydraulic conditions and riverbed materials, protection to scouring depth around the bridge piers should be provided. The riverbed protections around the piers and abutments should be sufficiently to ensure safety of the bridge piers against maximum scour depth. Gabion mattress apron is suitable to protect local scouring in flexible structures. Also, Nylon Fiber Gabion is more appropriate to protect scouring, if river bed is not flat.

3-3-4-3 River Bed Degradation

Piers supported on exposed concrete piles are commonly found in the Philippines (See Photo 3-1). This is caused by river bed degradation. Restoration of the river bed level is the best solution. To raise the river bed, wear or ground sill is provided at the downstream of the damaged bridge (See Photo 3-2).

The ground sill is the most appropriate method in restoring the river bed to its original level. However, it is necessary to design the scale of the ground sill in consideration with a hydrological study.

(Although concept of ground sill is suggested as a measure against river bed degradation, its methodology is not covered in this manual.)

Photo 3-1 Exposed Concrete Piles

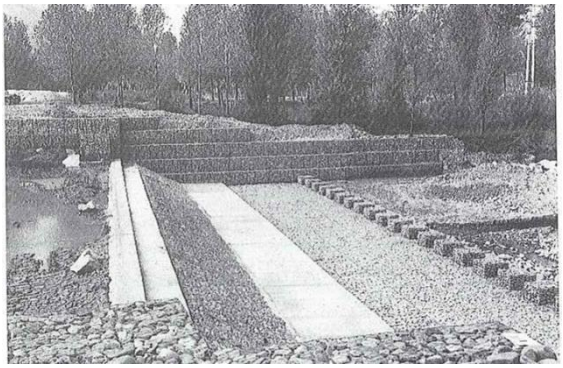


Photo 3-2 Ground Sill for Protection of River Bed Degradation (For Reference)

CHAPTER 4 REPAIR OF CONCRETE DECK SLAB

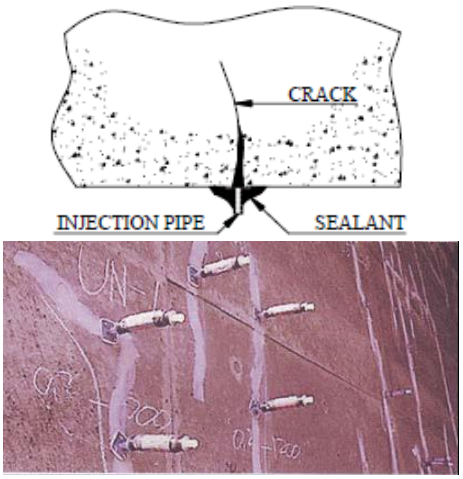
4-1 EPOXY INJECTION

4-1-1 Description of Repair Method

This method involves crack repairs to concrete structures, particularly to deck slab as shown in Figure 4-1. The works include preparation of concrete surface, insertion of pipe fittings bonded with adhesive, injection of epoxy, curing and conducting performance test.

Epoxy injection for concrete cracks requires highly skilled process and its effectiveness depends mostly on the proficiency of the certified applicator. Said applicator should be qualified based on his previous work records, and approved by the Engineer.

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



(After Injection)

Figure 4-1 Crack Injection Method

4-1-2 Application Criteria

Epoxy injection is used to restore structural soundness of structures exhibiting inactive cracks. Cracks with more than 0.3 mm up to 3.0 mm widths can be bonded and sealed by injecting low-viscosity epoxy.

4-1-3 Work Sequence

(1) Cleaning of 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 and effective solvent. Remove residual water or solvent in the crack with filtered (dust and oil free) compressed air and allow adequate time for drying.

(2) Adhesion of Pipe Fitting

Pipe fittings are bonded with 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.

(3) Sealing of Cracks at the Surface

Using a 5 cm width strap, epoxy sealant is applied on the area around the pipe fitting and cracks, allowing it to harden.

(4) Fitting of Injector

Connect the terminal of the injector to the pipe fittings.

(5) Injection of Epoxy

Epoxy shall be injected using air-activated epoxy injection guns as shown in Figure 4-2. Injection is performed on the pipe fitting. Duration of the injection operation shall be in accordance with the supplier's instruction.

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, epoxy injection is carried out from one end of the crack to the other, in a similar manner.

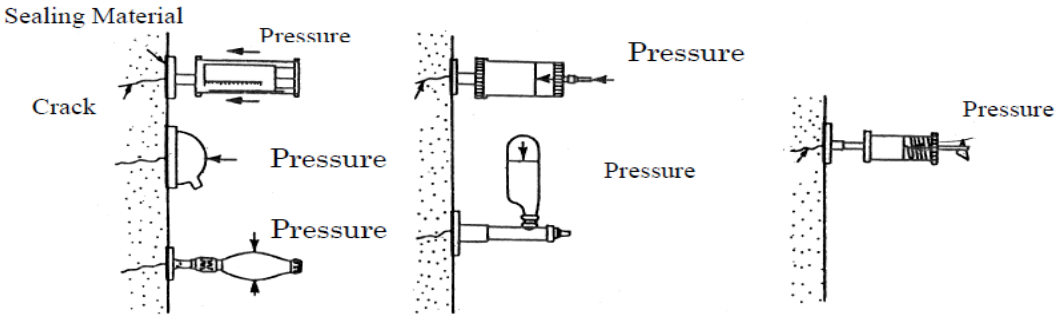


Figure 4-2 Crack Injection Method

(6) Curing of Injected Material

After the crack has been sealed, remove the projecting pipe fittings and fill holes with an epoxy patching compound. Surface coating will be applied, if required in the repair process.

4-1-4 Required Materials and Tools/Equipment

4-1-4-1 Required Materials

- Epoxy Resin
- Sealant
- Injection Port

4-1-4-2 Required Equipment/Tools

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

4-1-5 Specifications

4-1-5-1 Material Requirement

(1) Epoxy Resin

The epoxy resin shall be compatible with the host concrete and shall have the properties shown in Table 4-1. Testing of said properties shall be in accordance with the relevant standards shown in * milliPascal-second Table 4-2, or equivalent ASTM Specifications.

Table 4-1 Specifications of Epoxy Resin for Injection to Deck Slab (1/2)

Property	Test Method	Unit	Specification
Viscosity	JIS K 6833/ASTM D2393	mPa-s*	≤ 1000
Pot life	-	minute	60

* milliPascal-second

Table 4-2 Specifications of Epoxy Resin for Injection to Deck Slab (2/2)

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.15 ± 0.10
Compressive Strength	JIS K 7208/ASTM D695	N/mm^2	≥ 50
Modulus of Elasticity	JIS K 7208/ASTM D695M	N/mm^2	≥ 1000
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 40
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM D7234	N/mm^2	≥ 1.5 CF

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

CF – Concrete Failure

(2) Sealant

The epoxy-based sealant material shall be compatible with the injection material and shall have the properties listed in Table 4-3 below. Testing of materials shall be in accordance with the listed standards or equivalent ASTM Specifications.

Table 4-3 Specifications of Sealant (Putty) for Epoxy Injection to Deck Slab

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.50±0.30
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	≥ 50
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 15
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Bond Strength to Concrete (Dry/Wet)	JIS K 5400/ASTM D 7234	N/mm^2	≥ 1.5 CF

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

CF – Concrete Failure

4-1-5-2 Construction Requirement

(1) Preparation of Concrete

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, as stated in the Bridge Inspection Manual of BMS. 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 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 epoxy injection.

(2) Adhesion of Pipe Fitting

The pipe fittings shall be fixed at 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. Mixed 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

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, 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 when the ambient temperature is below or at 5^{O}C or on a falling thermometer, or is above 35^{O}C, without the Engineer's approval. The injection resin shall be of a pre-packed type and only its complete set will be allowed for use. 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.

(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.

(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 by inspection, such conditions shall be reworked at the Contractor's expense.

4-1-6 Method of Measurement and Payment

4-1-6-1 Method of Measurement

The method of measurement to determine payment for the epoxy injection works on cracks shall be based on the total length of the cracks, as identified by the Engineer.

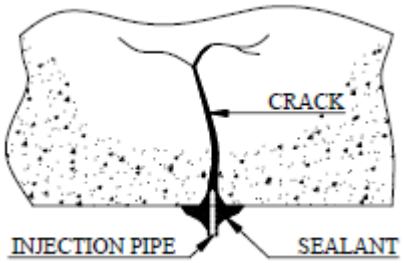
4-1-6-2 Basis of Payment

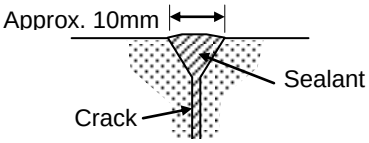
The contract price paid per meter for this work item shall include full compensation for supplying all labor, materials, tools, equipment, and incidentals, and for performing all the works involved in the preparation and injection of epoxy on cracks in the existing concrete, completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

4-2 CAULKING

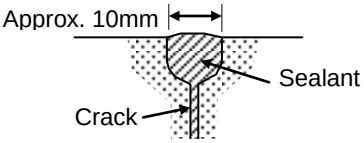
4-2-1 Description of Repair Method

Active cracks are treated as movement joints and repaired with flexible sealants as shown in Figure 4-3. 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.





(V-Type)



(U-Type)

Figure 4-3 Type of Caulking

4-2-2 Application Criteria

Crack widths could be more than 3.0 mm with depth of less than 300 mm. In this case, the top surface edges should be chipped or sawn to form V-type or U-type groove, in order to provide a caulking for inlet of gravity flow of resin into the crack by injection pump.

Cracks wider than 3.0 mm generally require epoxy-based injection material (mix of epoxy and mineral filler).

4-2-3 Work Sequence

(1) Cleaning of cracks.

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. Remove the residual water or solvent in the crack with filtered (dust and oil free) compressed air and allow adequate time for drying.

(2) Preparation of Caulking

Using a concrete saw, hand tools or pneumatic tools, a V-groove or U-groove, approximately 10 mm in width and in depth, is prepared at the surface along the crack. The groove shall then be partially sealed with a sealant.

(3) Drilling of Holes and Fixing of Injection Pipes

Port holes are drilled near the crack, or in the groove. Injection pipes are then fixed at the tip of the groove. Spacing between ports varies between 150 mm to 500 mm, generally depending on the width and depth of the cracks.

The groove is then completely sealed with sealant.

(4) Injecting the Epoxy Grout

Epoxy grout can be injected using injection pumps, or air-activated caulking guns. Duration of injection process shall be in accordance with the supplier instructions.

For horizontal cracks, the injection is carried out from the injection pipe at end of the crack to the other end.

(5) Curing of Injected Material

After the crack is sealed, the projecting injection pipes are cut and the holes are filled with epoxy patching compound. If surface coating or carbon fiber sheet will be applied, the portions with sealant and tip of cut pipe should be grinded to form a smooth surface.

4-2-4 Required Materials and Tools/Equipment

4-2-4-1 Required Materials

- Epoxy Grout
- Sealant

4-2-4-2 Required Equipment and Tools

- Grout Injection Pump or Gun
- Power Disc Grinder/Cutter
- Portable Generator
- Brush
- Set of Injection Tools

4-2-5 Specifications

4-2-5-1 Material Requirement

(1) Epoxy Grout

The epoxy grout material shall be compatible with the host concrete and shall have the properties listed in below Table 4-4. Testing of materials shall be in accordance with the relevant standards shown or equivalent ASTM Specifications.

Table 4-4 Specifications of Epoxy Based Injection Material to Deck Slab

Property	**Test Method**	**Unit**	**Specification**
Viscosity	JIS K 6833/ASTM D2393	mPa-s*	≤ 1000
Pot life	-	minute	60
Specific Gravity	JIS K 7112/ASTM D792	-	1.15 ± 0.10
Compressive Strength	JIS K 7208/ASTM D695	N/mm^2	≥ 50
Modulus of Elasticity	JIS K 7208/ASTM D695M	N/mm^2	≥ 1000
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 40
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM D7234	N/mm^2	≥ 1.5 CF

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

CF – Concrete Failure

(2) Sealant

The epoxy based sealant material shall be compatible with the injection material and shall have the properties listed in Table 4-5. Testing of materials shall be in accordance with the relevant standards as shown or equivalent ASTM Specification.

Table 4-5 Specifications of Epoxy Based Sealant to Deck Slab

Property	**Test Method**	**Unit**	**Specification**
Specific Gravity	JIS K 7112/ASTM D792	-	1.50±0.30
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	≥ 50
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 15
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Bond Strength to Concrete (Dry/Wet)	JIS K 5400/ASTM D 7234	N/mm^2	≥ 1.5 CF

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

CF – Concrete Failure

4-2-5-2 Construction Requirement

(1) Preparation of Concrete

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, as stated in the Bridge Inspection Manual of BMS. 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 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 for Caulking

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 4.2.1, at the surface along the crack. Clean the groove with an oil free air jet or wire brush and allow drying completely before placing the sealant. The sealant shall be applied in accordance with the manufacturer's instructions.

(3) Drilling Holes and Fixing the Injection Pipes

The injection pipes shall be fixed at intervals along the direction of each crack. The distance between each pipe shall be shown on drawings considering width and depth of crack, for approval of the Engineer. The 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 marker. Mixing is continued until a uniform paste is obtained.

Holes for injection pipes are drilled near the crack or in the groove until the tip of holes reach the full depth of crack. The injection pipes are inserted into the holes and fixed with epoxy adhesive. The mixed sealant shall be applied into the groove along the cracks as a caulking. 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.

(4) Grout Injection

Each crack shall be treated in a single, continuous operation. Sufficient grout material shall therefore be readily available prior to the commencement of the works.

The grout 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 grout material based on the study on the crack movement, subject to Engineer’s approval.

The preparation, mixing and application of the grout 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.

The injection resin shall be of a pre-packed type and only the use of full units will be allowed. 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 recommendations of the Engineer and the relevant governing rules and regulations.

(5) Curing

The grout shall be allowed to cure for twenty-four (24) hours and shall be left undisturbed during this time. The injection pipes are cut after confirmation of hardening. Cut the tip of injection pipe and the bands of surface sealant of caulking shall be smoothened for succeeding works.

(6) Performance Test

Conduct Low Frequency Pulse Velocity Ultrasonic Test to determine if the epoxy resin has penetrated the root of the crack. If incomplete penetration is revealed by test, such conditions shall be reworked by the Contractor, at his own expense.

4-2-6 Measurement and Payment

4-2-6-1 Method of Measurement

The method of measurement to determine payment for the caulking shall be based on the total length of the cracks, as identified by the Engineer.

4-2-6-2 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.

4-3 PATCHING

4-3-1 Description of Repair Method

Patch repair 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. The patch thickness is limited to a maximum of 100 mm depth of hollow surface.

Type A Patching is for defects without exposed rebars while Type B Patching is applied to surfaces with exposed rebars.

Patch repairs may be composed of portland cement mortars or non-shrinkage cement mortar, depending on the type of patching, location and extent of damage.

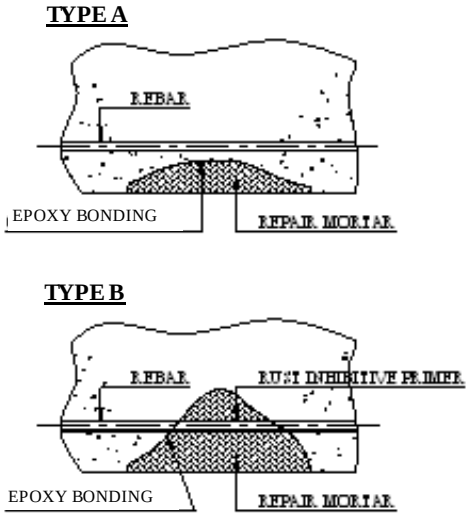


Figure 4-4 Types of Patching

4-3-2 Application Criteria

Patch repair is classified into two types as shown in Figure 4-4, considering defective area and surface. Type-A is applicable to surfaces without exposed rebars, having defective widths of up to 300 mm and depth of up to 50 mm. Type-B is for surfaces with exposed rebars, with defective widths between 300 mm and 600 mm, and up to 100 mm depth.

Portland cement mortar and polymer cement mortar is used for Type-A and Type-B patching, respectively.

4-3-3 Work Procedure

(1) Removal of Defective Concrete

Remove all defective, unsound and contaminated concrete and prepare the edges for the patch area. If local corrosion in reinforcement with section loss is found, which would require additional bars, remove only the damaged area of concrete including the length needed to bond the new reinforcement as shown in Figure 4-5.

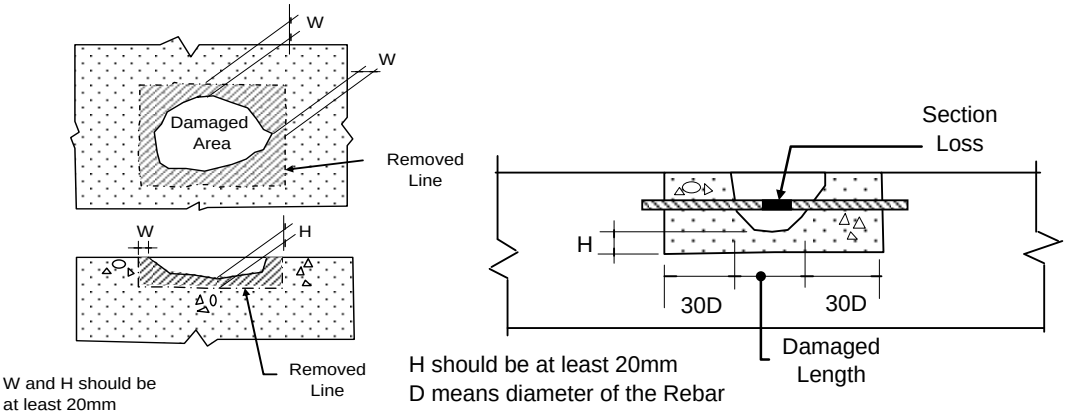


Figure 4-5 Limits of Removal of Damaged Concrete

(2) Cleaning of Surfaces 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. 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 and has developed pits, use water abrasive blasting until all the rust is removed

(3) Applying Epoxy Bonding Coats 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 epoxy bonding coat to steel bars with a brush working vigorously to ensure that they are evenly covered all around.

(4) Placing Mortar

The mortar should be placed in layers of about 20 mm thick. 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 patching to the surrounding concrete is performed using a form material, and then hammered using a mallet, wood floating or steel trowel.

(5) 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.

4-3-4 Required Materials and Tools/Equipment

4-3-4-1 Required Materials

Portland Cement Mortar	**Polymer Cement Mortar (PCM)**
- Portland Cement	- PCM Powder

- Sand
- Water
- Concrete Nail
- Bonding Agent to Concrete (Epoxy Bonding)

- PCM Emulsion
- Concrete Nail
- Bonding Agent to Concrete (Epoxy Bonding)

4-3-4-2 Required Equipment

- Chisel
- Portable Generator
- Wire Brush
- Small Hammer
- Mortar Mix Bucket
- Safety Goggles
- Trowel
- Scaffolding or Inspection Vehicle

4-3-5 Specifications

4-3-5-1 Material Requirement

Portland Cement Mortar shall conform to the requirements of Item 405, Structural Concrete, DPWH Standard Specifications. Strength test for Portland cement mortar shall be based on ASTM C 780

The polymer cement mortar shall conform to the requirements of the specifications shown in Table 4-6, JIS or equivalent ASTM Specifications.

Table 4-6 Specification of Polymer Cement Patching Material

Property	Test Method	Unit	Specification
Compressive Strength	JSH 416/ASTM C39	N/mm^2	At 28 days: ≥ 25
Bonding Strength to Concrete	JHS 416/ASTM D 7234	N/mm^2	≥ 1.5
Bleeding Rate	JHS 416/ASTM C 39	%	0

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

The Protective Coating of rebar shall conform with the requirements of the specifications in Table 4-7.

Table 4-7 Specification of Protective Coating for Rebar

Property	Test Method	Unit	Specifications
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	75
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	40
Tensile Strength	JIS K 7113/ASTM D638M	N/mm^2	30

Tensile Shear Bond to Steel	JIS K 6850/ASTM D1002	N/mm^2	10
Slant Shear Bond to Mortar	JIS K6852/ASTM C882	N/mm^2	15

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

The zinc-rich primer to be applied to rebar shall be in accordance with the requirements of the specifications in Table 4-8.

Table 4-8 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 D 117	-	Excellent
%Zinc by Weight in Dried Film Test	-	%	87.5±2

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

4-3-5-2 Construction Requirement

(1) Removal of Damaged Concrete

Concrete within marked out areas shall be removed using light mechanical breakers or hammer and chisel. Cut the exposed reinforcement and determine the soundness of the concrete substrate to the satisfaction of the Engineer, without breaking the concrete behind the reinforcement.

(2) Preparation of Concrete Surface

All concrete surfaces that are to receive repair mortar 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 from the method of preparation 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, the Contractor shall be informed and an enlarged area shall be agreed to be broken to the satisfaction of the Engineer.

The Contractor shall test the concrete for depth 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 order to remove all carbonated concrete. The additional concrete breakout shall not extend to more than 20 mm behind the bottom layer main reinforcement. During breakout, utmost care shall be undertaken to minimize damage to 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 be 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) Method of Placing Mortar

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. 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. 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.

(6) Curing

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.

4-3-6 Measurement and Payment

4-3-6-1 Method of Measurement

The Engineer will measure the area prepared for patching 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.

4-3-6-2 Basis of Payment

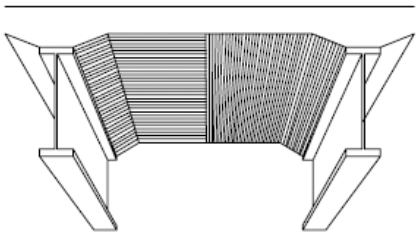
The price and payment per square meter of patching shall include full compensation for removal of deteriorated concrete, surface cleaning and preparation, furnishing and placing all materials, labor, equipment and tools. It shall also include construction and removal of formworks and other temporary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

4-4 CARBON FIBER SHEET BONDING TO DECK SLAB

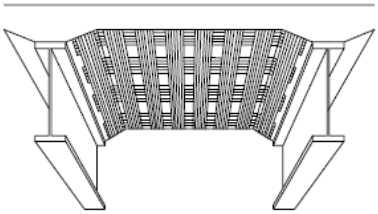
4-4-1 Description of repair Method

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 4-6 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.



Continuous Arrangement



Grid Arrangement

Figure 4-6 Arrangements of Carbon Fiber Sheet

4-4-2 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, were found in the installed CFS. These air voids reduce bond strength between CFS and concrete surface and must be squeezed out 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 same as 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 4-7.

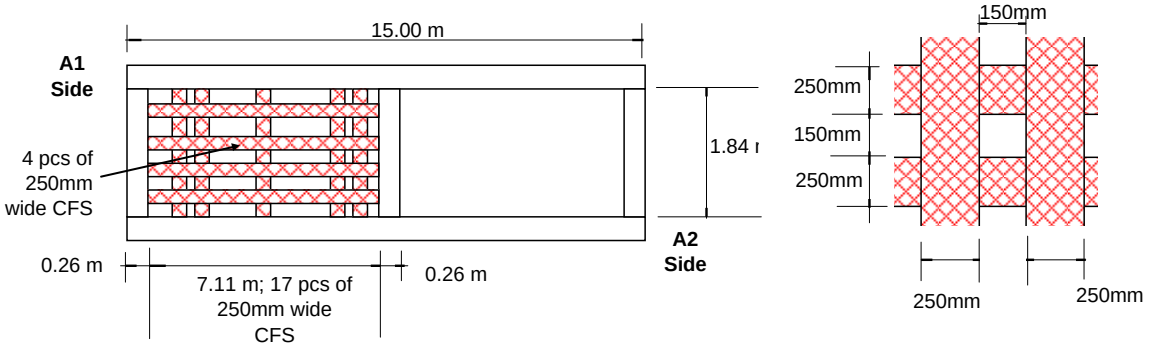


Figure 4-7 Arrangement of CFS (For Reference)

4-4-3 Work Sequence

(1) Preparation of Concrete

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

(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.

(3) Adjustment of Unevenness with Putty

Any concave, pores, gaps on the concrete surface must be smoothened using epoxy putty.

(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 permeates into the CFS.

(5) Installation of Longitudinal Layer CFS

Properly aligned CFS strips are installed in longitudinal direction to the adhesive coated concrete surface.

Press the carbon fiber sheet by using plastic roller starting from the center toward the edge.

(6) Installation of Transversal Layer CFS

Properly aligned CFS strips are installed in transversal direction to the adhesive coated concrete surface.

Press the carbon fiber sheet by using plastic roller starting from the center toward the edge.

(7) Squeezing out of Entrapped Air

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

(8) Surface Protection

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

4-4-4 Required Materials and Tools/Equipment

4-4-4-1 Required Materials

Carbon Fiber Products

- CFS (Strap Type)

Epoxy Materials

- Epoxy primer
- Epoxy putty
- Epoxy resin adhesive

4-4-4-2 Required Equipment

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

4-4-5 Specifications

4-4-5-1 Material Requirement

The CFS shall conform to the requirements of the specifications shown in Table 4-9, or equivalent ASTM Specifications.

Table 4-9 Specifications of CFS to Deck Slab

Property	Test Method	Unit	Specifications
Carbon fiber weight	JIS K 7071	g/m^2	200
Tensile Strength	JIS K 7073/ASTM D3039	N/mm^2	≥ 3400
Overlap Tensile Strength	JIS K 7073/ASTM D3039	N/mm^2	≥ 3400
Tensile Bond to Concrete (Dry/Wet)	JIS K5400/ASTM D7234	N/mm^2	≥ 1.5 CF

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

CF – Concrete Failure

The epoxy adhesive shall conform to the requirements of the specifications shown in Table 4-10.

Table 4-10 Specifications of Epoxy Resin Adhesive for CFS

Property	Test Method	Unit	Primer	Epoxy Putty	Penetrating Epoxy Resin
Viscosity	JIS K 6833/ ASTM D2393	mPa-s	≤ 1000	Paste-like	15,000±5000
Modulus of Elasticity	JIS K 7208/ ASTM D695M	N/mm^2	≥ 1500	≥ 1500	≥ 1500
Slant Shear Bond to Concrete	ASTM C882	N/mm^2	≥ 15	≥ 15	≥ 15
Bond Strength to Concrete (Dry/ Wet)	JIS K5400/ ASTM D7234	N/mm^2	≥ 1.54	≥ 1.54	≥ 1.54

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

4-4-5-2 Construction Requirement

(1) Surface Preparation

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

(2) Material Handling

The carbon fiber components shall be delivered in an 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 related products shall be in conformance with manufacturer's recommendations and instructions.

(3) Prime Coat

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, storming or air is misty or when condition remains 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) Putty Application

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

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 coated surface should be roughened with sandpaper and cleaned before the resin application

The contact surface condition shall be tack-free and application shall not be done when raining, storming, 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.

- Mix the 2 parts of epoxy resin until homogenized,
- Apply the epoxy resin on the surface at s rate of 0.5 kg/sq.m,

(6) CFS Application (Longitudinal Direction)

The standard length of carbon sheet will be cut to 4 to 6 m. If standard cut length is exceeded, wrinkles will appear and installation becomes more difficult. The CFS shall be applied as per the following:

- Stick the CFS in the longitudinal direction with a reasonable lapse of 20~30 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.

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 in the work site, subject to Engineer's approval.

(7) Over Coating Resin Application

Mixing and application procedure for the over coat shall be similar to that of the under-coating resin. The standard quantity of over-coating resin is 0.2 kg/m^2. The actual quantity should be determined in consideration with ambient temperature and manufacturer's recommendation in the work site, subject to Engineer's approval.

(8) CFS Application (Transversal Direction)

After all longitudinal layer CFS application, the transversal layer CFS is applied at right angles to each other in same manner as the longitudinal direction.

(9) Quality Control and Inspection

The Contractor shall conduct a quality control program that includes, but 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 is in accordance with DPWH Standard Specifications, and approved manufacturer's instructions.
- 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^2 (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.

4-4-6 Measurement and Payment

4-4-6-1 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.

4-4-6-2 Basis of Payment

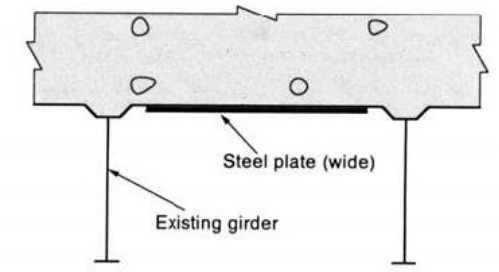
The quantity, measured as prescribed above, shall be paid for at a contract unit price. Epoxy injection of cracks will not be paid for directly and is considered subsidiary to the works. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related services 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.

4-5 STEEL PLATE BONDING

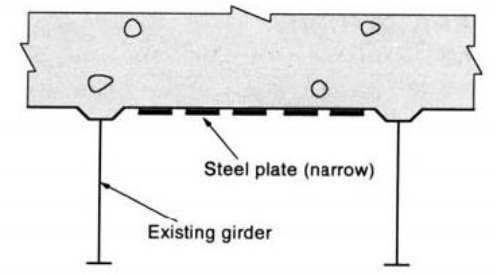
4-5-1 Description of Repair Method

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 viability of this technique for a particular structure should be considered carefully due to its sensitivity to standards of workmanship and need for regular in-service inspection. Economical evaluation should be carried out in order to compare this technique with other methods of strengthening. The effect of bonding a plate to the tension face of a reinforced concrete section is to increase the depth from the compression face to the neutral axis and the area of effective reinforcement, thus, increasing the moment of resistance of the section.

The steel plate bonding has two types, namely, wide plate and narrow plate as shown in Figure 4-8. Wide plates are used for strengthening the slab in both the main reinforcing bar and distribution bar directions. Narrow plates are used for strengthening the slab in one direction only.



Wide Plate Type



Narrow Plate Type

Figure 4-8 Types of Steel Plate Bonding

4-5-2 Application Criteria

Type of steel plate bonding (wide and narrow steel plates) to be applied shall be according to the direction of the damaged rebar of the deck slab, as discussed above. The bonding of steel plates to concrete members has been undertaken considering two methods as follows:

Injection Method

This method involves single plates of required thickness, with gaps sealed at the edges between the steel and the concrete. Resin is then pumped ensuring that no voids occur between the plate and the concrete as shown in Figure 4-9.

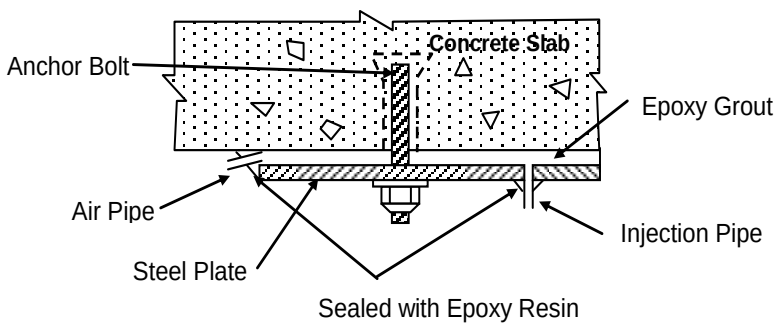


Figure 4-9 Detail of Injection Method Sealing with Epoxy Adhesive

Pressure Attaching Method

Similar to injection method, this requires single plates of required thickness with gaps sealed at the edges between the steel and the concrete. However, epoxy resin in this method is injected to ensure that no voids occur between the plate and the concrete.

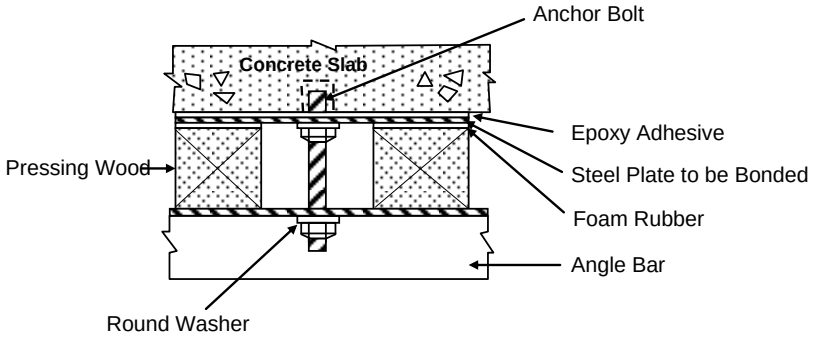


Figure 4-10 Detail of Pressure Attaching Method by Anchor Bolts

Injection method should be applied for wide plate type while pressure attaching method for narrow plate type, with due consideration to the extent of surface preparation of both concrete and steel plate.

4-5-3 Work Sequence

4-5-3-1 Injection Method

(1) Surface Preparation

Bottom surface of slab to be bonded with steel plate shall be cleaned. Any surface irregularities shall be leveled using a disc grinder.

The surface of the steel to be bonded must be completely free of any mill scale, rust, grease or other contaminants. The primer should be applied on the surface which is compatible with the adhesive.

(2) Setting of Steel Plate on the Slab

Injection pipes are attached to the steel plate. Anchor bolts shall be provided to temporarily support steel plates (placed below the slab surface with an average gap of 5 mm) in the event of that the deck slab settles. Joints between steel plates are welded at site.

(3) Sealing of Steel Plate

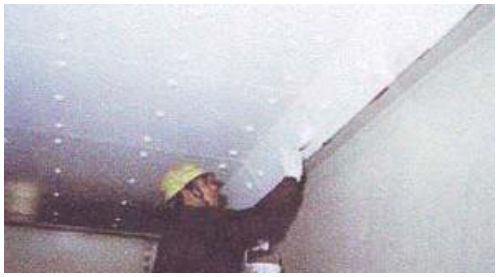
The periphery of the steel plate is sealed with epoxy putty as well as the area surrounding the injection holes.

(4) Injection of Epoxy Resin

Mixing is continuously done during the injection. Inject the epoxy grout through injection pipes to fill the gap between the plate and the concrete.

(5) Curing and Painting

A suitable chamfer/fillet could also be formed in the adhesive around the edge of the plates and the concrete surfaces. Steel plates and all its components shall be adequately painted for corrosion protection.



4-5-3-2 Pressure Attaching Method

(1) Surface Preparation

Bottom surface of slab bonded with steel plate shall be cleaned. Any surface irregularities shall be leveled using a disc grinder.

The surface of the steel to be bonded must be completely free of any mill scale, rust, grease or other contaminants. The primer should be applied on the surface which is compatible with the adhesive.

(2) Application of Epoxy Resin

The adhesive shall be thicker along the center of the steel plate than at the sides. The use of plastic spacers maintains minimum adhesive thickness of 1- 2 mm

(3) Pressure Attachment of Steel Plate

The epoxy resin adhesive is applied to the steel plate which is set at the required position of the deck slab, and pressed using the anchor bolts wedging off with the temporary stiff wood and angular.

(4) Curing and Painting

A suitable chamfer/fillet could also be formed in the adhesive around the edge of the plates and the concrete surfaces. Steel plates and all its components shall be adequately painted for corrosion protection.

4-5-4 Required Materials and Tools/Equipment

4-5-4-1 Required Materials

Injection Method

- Steel Plate
- Primer (Epoxy Base)
- Epoxy Resin Adhesive for Injection
- Epoxy Sealant
- Anchor Bolts

Pressure Attaching Method

- Steel Plate
- Primer (Epoxy Base)
- Epoxy Resin Adhesive
- Epoxy Sealant
- Anchor Bolts
- Wood and Angle for Fitting

4-5-4-2 Required Tools/Equipment

Injection Method

- Disc Grinder
- Welder
- Electric Drill
- Epoxy Injection Pump with Accessories
- Wire Brush

Pressure Attaching Method

- Disc Grinder

- Welder
- Electric Drill
- Epoxy Injection Pump with Accessories
- Wire Brush

4-5-5 Specifications

4-5-5-1 Material Requirement

The Steel Plate to be used shall be in accordance with ASTM A36 used in DPWH Standard Specifications Item 409.

The epoxy resin adhesive shall conform with the requirements of the specifications shown in Table 4-11 to Table 4-13, or equivalent ASTM Specifications.

Table 4-11 Specification of Epoxy Grout for Steel Bonding to Concrete

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.15±0.1
Viscosity	JIS K 6833/ASTM D2393	mPa-s	≤ 1000
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 40
Compressive Strength	JIS K 7208/ASTM D695	N/mm^2	≥ 50
Modulus of Elasticity	JIS K 7208/ASTM D695M	N/mm^2	≥ 1000
Bond Strength to Concrete (Dry/Wet	JIS K5400/ASTM D 7234	N/mm^2	> 1.5 CF
Tensile Shear Bond to Steel	JIS K 6850/ASTM D1002	N/mm^2	≥ 15

The material shall be approved by the Engineer through mill certificate of the supplier. CF – Concrete Failure

Table 4-12 Specification of Epoxy Sealant for Steel Bonding to Concrete

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.50±0.3
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 15
Compressive Yield Strength	JIS K 7208/ASTM D695M	N/mm^2	≥ 50
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Slant Shear Bond to Concrete	JIS K6852/ASTM C882	N/mm^2	≥ 15

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

Table 4-13 Specification of Epoxy Resin Adhesive for Steel Bonding to Concrete

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.16±0.1
Flexural Strength	JIS K k 7203/ASTM D790M	N/mm^2	≥ 40
Compressive strength	JIS K 7208/ASTM D695M	N/mm^2	≥ 70
Tensile Strength	JIS K 7113/ASTM D638	N/mm^2	≥ 40
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 15
Bond Strength to Concrete Dry / Wet	JIS K5400 / ASTM D7234	N/mm^2	≥ 3,5

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

4-5-5-2 Construction Requirement

(1) Injection Method

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.

Steel Plate Setting

Steel Plate shall comply with JIS or DPWH Standard (ASTM A36). Yield strength should not less than 240 N/mm^2 which is equivalent to JIS SS400 or ASTM A36. Minimum plate thickness should not be less than 4 mm in order to avoid distortions during grit blasting and handling on site. 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 within the defined space. Concrete structures to which plates are to be bonded shall be invariably smoothened and surface burnished using a disc grinder.

Injection of 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, mix continuously 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.

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 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.

(2) Pressure Attaching Method

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 allow loss of adhesive 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 fabricators premises. The primer, for the epoxy resin adhesive, should be an epoxy based system which is compatible with the adhesive.

Steel Plate Setting

Steel plate shall comply with JIS or Equivalent Standard. The use of high yield steel does not exceed 150 N/mm² which is equivalent to SS400 class for JIS Standard. Minimum plate thickness should not be less than 4mm in order to avoid distortions during grit blasting and handling on site. Anchor bolts are required to temporarily support steel plates in the event of setting on the deck slab. The bolt spacing should be sufficient to prevent deflection of the bonded plate within the defined space. Concrete structures to which plates are to be bonded shall be invariably smoothened and surface burnished using a disc grinder.

Application of Epoxy Resin

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. Epoxy resin adhesive shall be spread immediately after mixing to dissipate the heat generated and extend its workability time. The adhesive spread shall be thicker along the center of the steel plate than at its sides. The use of plastic spacers maintains the minimum adhesive thickness of 1-2 mm. Excess adhesive can then be scraped.

Pressure Attachment of Steel Plate

The epoxy resin adhesive is applied to the steel plate which is set at the required position of the deck slab, and pressed using the anchor bolts wedging off with the temporary stiff wood and angle bar, in accordance with the shop drawings approved by the Engineer.

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 could also be formed in the adhesive around the edge of the plates and the concrete surfaces. Steel plates and all associated components shall be adequately painted for corrosion protection.

4-5-6 Measurement and Payment

4-5-6-1 Basis of Measurement

Steel plate bonding 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 meter, accepted by the Engineer. No measurement will be made for epoxy injection of cracks, if required.

4-5-6-2 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.

4-6 PARTIAL DECK SLAB REPLACEMENT

4-6-1 Description of Repair Method

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 4-1, 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.

Photo 4-1 Severely Damaged Deck Slab

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 Figure 4-11.

If the bridge cannot be closed to traffic during repair, it is suggested to use fast-setting mortar instead of Portland cement concrete.

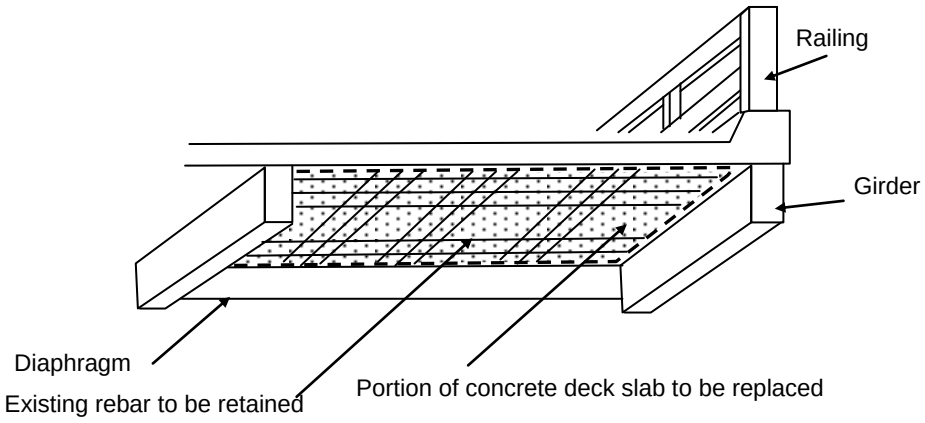


Figure 4-11 Detail of Partial Deck Slab Replacement

4-6-2 Application Criteria

The method of placement of slab concrete depends largely on particular situation. Nevertheless, it should ensure that well compacted concrete completely fills all the voids. The works generally include complete removal of defective concrete and its adjacent surfaces to its full depth, setting formworks, cleaning the existing rebar (and additional rebar, if required) and placing new concrete. Alternatively, only partial depth of the defective concrete will be removed, while the soffit formwork can be extended to provide a series of hoppers at its open sides, to allow for filling of super plasticized "flowing" concrete.

Said alternative method (Partial Depth) is similar to the recasting method for repair to girder and substructure, discussed in separate sections in this manual. However, it is not expected to be as effective considering the wide area and limited thickness of deck slab, subjected to repeated loadings

due to traffic. In this manual, the first method (Full Depth), which is replacement of concrete by defect section or panel, is recommended for repair of severely damaged deck slab.

4-6-3 Work Sequence

(1) Support of Existing Structure

The existing structure shall be properly supported to safeguard against instability and deformation during the repair work.

(2) Removal of Deck Slab Concrete

All deteriorated or damaged concrete surface are cut by saw, forming vertical edges, and then removed using breaker and chisel. Rebar 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.

(3) Preparation of Old Concrete and Rebar

A suitable bonding agent for concrete and reinforcement should be selected taking into consideration the limited working time available for fixing the formwork and placing the new concrete. Concrete should be placed immediately after application of the bonding coat to the faces of the old concrete and rebar.

(4) Setting of Formworks

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

(5) Cutting of Existing Rebar and Addition of New Rebar

Deteriorated old rebar are cut up to the required lap length. New bars to be provided shall be of same or bigger diameter than the existing, considering the current loading condition. The lap length is calculated as 30 times the new rebar diameter. The new rebar shall be tied to the existing bars using tie wires or by welding.

(6) Placing of Concrete

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

(7) Curing and Removal of Formworks

Continuous water curing with wetted cotton mat is always preferable to slow down drying.

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.

4-6-4 Required Materials and Tools/Equipment

4-6-4-1 Required Materials

- Portland Cement
- Silica Fume
- Rebar (Reinforcing bar, use Grade 40 for 16mm diameter)
- Epoxy Resin (Bonding Coat to Concrete)
- Zinc Rich Primer (Bonding Coat to Rebar)

4-6-4-2 Required Tools/Equipment

- Sawing Equipment
- High Pressure Water Blasting
- Handy Concrete Breaker or Jackhammer
- Handy Power Chisel
- Concrete Mixer 30 liters
- Vibrator
- Troweling tools

4-6-5 Specification

(1) Removal of Concrete

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 portable electric chisel is used near the vertical edges.

(2) Concrete Mix

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.

1) Cement
   - Portland cement 13.0 kg
   - Silica fume 0.5 kg (If silica fume unavailable, use 13.5kg cement)

2) 10mm Crushed Aggregate 36.0 kg

3) Sand (assumed with 2% water content) 18.5 kg

4) Water (maximum) 5.4 liters

5) Super plasticizer (nominal) 25ml

(3) Adding 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.

Tying of loose bars will be required. Rebar which have been cut or have lost 20 percent or more of their original cross sectional area shall be supplemented with new reinforcing bars. The new bars shall be lapped a minimum of 30 times the new diameter to the existing bars, which shall be coated with zinc-rich primer. An approved mechanical bar splice capable of developing tension of at least 125 percent of the yield strength of the existing bar shall be used when it is not feasible to provide the minimum bar lap.

(4) Concrete Placement

The concrete shall be placed and consolidated according to Item 405.4.4 of the DPWH Standard Specifications.

4-6-6 Measurement and Payment

4-6-6-1 Basis of Measurement

Partial deck slab replacement performed in accordance with the plans and the specification 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 rebar will be in accordance with the DPWH Standard Specifications.

4-6-6-2 Basis of Payment

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

4-7 WATERPROOFING ON DECK SLAB

4-7-1 Description of Repair Method

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.

The bridge deck waterproofing includes the sheet system and liquid (Membrane) system. The sheet system is widely applied in European countries by a qualified contractor. However, it is difficult to implement this system in the Philippines since, at present, no qualified contractor has an experience in the related work methods.

On the other hand, liquid system involves a simple procedure similar to painting method. Many skilled workers in the Philippines are qualified and experienced in utilizing this system. In this repair manual, two types of liquid system are introduced, namely, Rubberized Membrane Type (Photo 4-2) and Asphalt Compound Membrane Type (Photo 4-3).

Photo 4-2 Rubberized Membrane Type

Photo 4-3 Asphalt Compound Membrane Type

4-7-2 Application Criteria

The rubberized type waterproof membrane mainly consists of chloroprene rubber. The asphalt compound type meanwhile consists of asphalt mixed with special rubber, which is melted in a mechanically agitated heating process. (See Figure 4-12)

The first type is recently developed and used widely for deck waterproofing. Application procedure is very simple and final product is proven to have good performance. However, rubberized membrane is more costly than asphalt compound membrane. Furthermore, if asphalt removal is required on the deck, which is difficult to remove completely, this membrane type will not be ideal since the roughness of the deck surface, reduces its waterproofing efficiency.

The second system involves less costly materials. However, equipment costs such as kettle and heating tool, including its inland transport cost tends to somehow increase related construction cost. In this manual, the second system is recommended considering ease of application and low cost as well as its good performance.

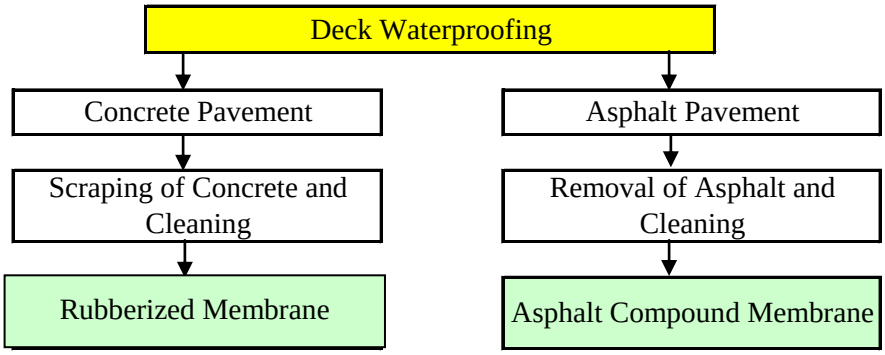


Figure 4-12 Flowchart for Selection of Waterproofing

4-7-3 Work Sequence

4-7-3-1 Rubberized Membrane

Rubberized membrane is composed as shown in Figure 4-13.

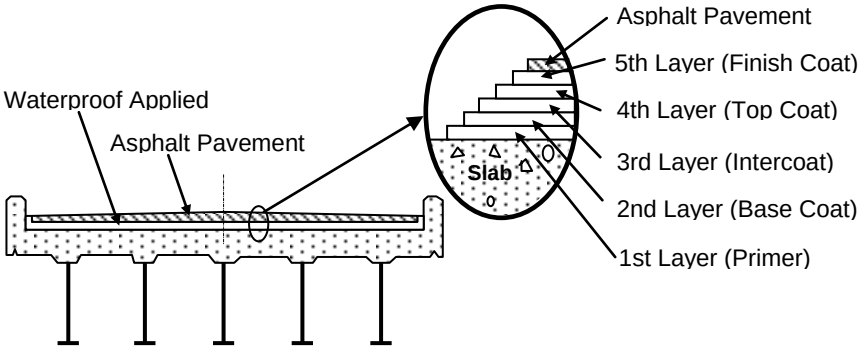


Figure 4-13 Composition of Layer for Rubberized Membrane

(1) Preparation of Deck Surface

Deck surface shall be cleaned by wire brush, removing oil, asphalt and concrete chips and dust that will affect adhesion to the substrate. The substrate shall be kept dry during the waterproofing works

(2) 1st Layer (Primer)

Primer coat shall be applied once or twice on the cleaned substrate using a roller brush. The coating is approximately 0.2 kg/m^2 and natural dried for more than 30 minutes until tack-free. (Refer also to Manufacture's instruction).

(3) 2nd Layer (Base Coat)

Base coat as 2nd layer is a rubberized membrane which is applied on the primer using a roller brush, to form a uniform film with consistent thickness (Approximately 0.4 kg/m^2)

(4) 3rd Layer (Intercoat)

Intercoat, the 3rd layer, is a rubberized membrane which is applied on the base coat using roller brush, to form a uniform film with equal thickness (Approximately 0.4 kg/m^2)

(5) 4th Layer (Top Coat)

Top Coat, the 4th layer, is a rubberized membrane applied on the intercoat using roller brush to form a uniform film with equal thickness (Approximately 0.4 kg/m^2)

(6) 5th Layer (Tack Coat)

Tack Coat, 5th layer, is an asphalt base coating which is applied on the top coat using a roller brush, for better bonding to asphalt pavement. (Approximately 0.1 kg/m^2)

(7) Asphalt Pavement

For adequate protection of the waterproofing membrane, the application of the asphalt road surface is carried out after tack coat is cured.

4-7-3-2 Asphalt Compound Membrane

Asphalt Compound membrane is composed of layers as shown in Figure 4-14.

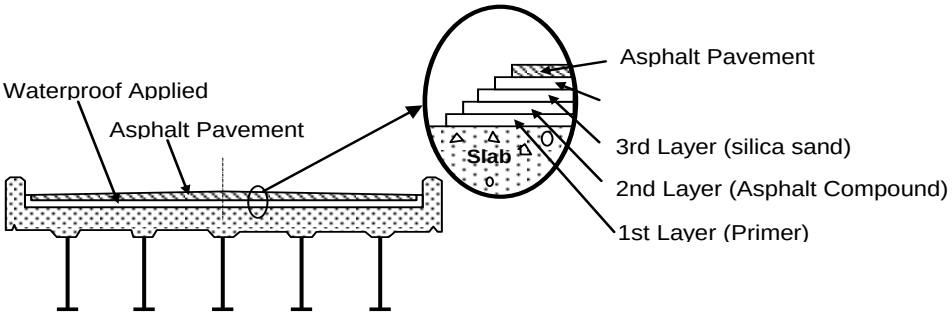


Figure 4-14 Composition of Layer for Asphalt Compound Membrane

(1) Preparation of Surface

Existing asphalt pavement is stripped off and removed totally. The deck surface shall be cleaned using a wire brush, removing oil, asphalt and concrete chips and dust that will affect adhesion to the substrate. The substrate shall be kept dry during the waterproofing works

(2) Primer Coating

Primer coat shall be applied once or twice on the cleaned substrate using a roller brush. The coating is approximately 0.2 kg/m^2 and natural dried for more than 30 minutes until tack-free. (Refer also to Manufacture's instruction).

(3) Melting Asphalt Compound

Asphalt membrane shall be melted in the mechanically agitated heating process 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.

(4) Application of Asphalt Compound

The asphalt membrane shall be applied using a rubber brush within the temperature range recommended by the Manufacturer, to the clean, primer-coated concrete deck, forming a uniform film with equal thickness (Approximately 1.2kg/m^2). The laying operation shall eliminate discontinuities in the membrane.

(5) Application of Silica Sand for Protection

Silica sand shall be scattered on the waterproofing layer while the membrane is still hot. The silica sand to be used shall be approximately 0.7 kg/m^2. (Refer to the Manufacture's instruction).

(6) Curing/Asphalt Pavement

Curing must be carried out until waterproofing membrane is cooled down to normal temperature. Excess silica sand shall then be removed using a broom. Asphalt overlay is then finally applied.

4-7-4 Required Materials and Tools/Equipment

4-7-4-1 Required Material

(1) Rubberized Membrane

- Primer
- Rubberized Membrane (2nd layer ~ 4th layer)
- Tack Coat (Finish Coat)

(2) Asphalt Compound Membrane

- Primer
- Asphalt Compound Membrane
- Silica sand No.4

4-7-4-2 Required Equipment/Tools

(1) Rubberized Membrane

- Paint Roller

(2) Asphalt Compound Membrane

- Kettle with Heater
- Roller Brush or Hair brush
- Rubber Brush

4-7-5 Specifications

4-7-5-1 Material Requirement

(1) Rubberized Membrane

Waterproofing by rubberized membrane shall conform to the requirements of the Specifications as shown in Table 4-14 or equivalent ASTM Specification.

Table 4-14 Specifications of Rubberized Membrane

Property	Test Method	Unit	Specification
Elongation	JIS K 6021/ASTM D 638	%	450
Tensile Strength	JIS K 6021/ASTM D 638	Kgf/cm^2	15
Concrete Bond Strength	JHERI 410/ATMS D 882	Kgf/cm^2	7

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

(2) Asphalt Compound Membrane

Primer

Primer specifications shall be similar to that required for rubberized membrane.

Waterproofing by asphalt compound membrane shall conform to the requirements of the specifications shown in Table 4-15, or equivalent ASTM Specification.

Table 4-15 Specifications of Asphalt Compound for Waterproofing

Property	Test Method	Unit	Specification
Penetration with Conic Needle	JIS K 5400/ASTM D217	mm	2 ~ 5
Melting Temperature	JIS K 6839/ASTM D3461	℃	80
Elongation	JIS K 6021/ASTM D 638	%	3.5
Tensile Strength	JIS K 6021/ASTM D 638	Kgf/cm^2	300

The material shall be approved by the Engineer through mill certificate of the supplier. Primer, tack coat and silica sand shall be in accordance with DPWH Standard Specifications.

4-7-5-2 Construction Requirement

The Contractor shall submit shop drawings for the waterproofing application, slab drain and spray mesh 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) Rubberized Membrane

Surface Preparation

The deck concrete, including curbs, sidewalks and medians must be completely dry and cured at least 14 days before application of primer or membrane can proceed. The existing surface of the concrete shall be completely sandblasted or shot wire brush 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.

Primer Coating

Immediately prior to the application of the primer coat, the concrete surface shall be air blasted to remove all dust and any other foreign material. 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℃. Waterproofing equipment or material shall not be permitted on the primer coat until it has fully cured and is completely tack-free.

Application of Rubberized Membrane

3 to 4 layers of rubberized membrane are applied manually using roller brush. The proper time allowance for the curing process between new layer and preceding layer shall be in accordance with the manufacturer's instructions. The curing time could be modified considering the weather conditions likely to affect the waterproofing operation subject to the approval of the Engineer.

Application of Tack Coating

Tack coating, the 5^{th} layer consisting of Rubberized Membrane, is an asphalt base coating applied on top of waterproofed membrane for better bonding to asphalt pavement.

(2) Asphalt Compound Membrane

Surface Preparation

The deck concrete, including curbs, and sidewalks 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 brush 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.

Immediately 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℃. Waterproofing equipment or material shall not be permitted on the primer coat until it has fully cured and is completely tack-free.

Melting Asphalt Compound

Asphalt membrane shall be melted in the mechanically agitated heating 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.

Application of Asphalt Compound

Asphalt Membrane shall not be applied until the primer has cured completely. The 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 1.2kg/m^2). 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.

Application of Silica Sand for Protection

Silica sand shall be scattered 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^2. (Refer to the manufacturer's instructions)

4-7-6 Measurement and Payment

4-7-6-1 Basis of Measurement

Deck slab waterproofing membrane, 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 DPWH Standard Specifications.

4-7-6-2 Basis of Payment

Payment for Deck Waterproofing 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.

4-8 FAST SETTING MORTAR FOR CONTINUED DECK SLAB

4-8-1 Description of Repair Method

Most of RCDG bridges are simple span bridges. Furthermore, there are many multiple span RCDG bridges designed as simple spans with gaps between the spans. In order to strengthen the stability of the bridge structure, continued deck slab method is adopted to reduce the bridge maintenance work and to maintain good performance.

Continued deck slab is used to connect the deck slabs only. The working stress of the main girder is still as same as in original design of simple span girder, because the stiffness of deck slab is very small compared to the stiffness of main girder. It is important to consider that cost of continued deck slab is less than the cost of the continued girders .

Additional rebar of longitudinal direction are required for continued deck slab. Additional rebar are placed at bottom side and upper side of slab.

If the deck slab is required to replace by half-lane at a time, additional rebar of transverse direction should be installed for connection each half-lane. Rebar coupler is very useful in connection of each rebar. The end of the additional transverse rebar should be threaded for connection of coupler. During repair works, traffic control must be maintained.

Threaded rebar and rebar coupler are fabricated in a machine shop. Material of Rebar coupler is high carbon steel.

Photo 4-4 Rebar for Continued Deck Slab

Photo 4-5 Completion of Pouring of Fast-Setting Mortar

4-8-2 Application Criteria

The works generally include complete removal of defective concrete and its adjacent surfaces to its full depth, setting formworks, cleaning the existing rebar (and placing additional rebar) and placing fast-setting mortar.

If ordinary concrete is used for continued deck slab, it is necessary to observe enough curing time to reach the 28 days design compressive strength of concrete prior to opening to traffic,

In order to shorten curing time, fast-setting mortar shall be used. The material is allowed to reduce curing time around a few days for shorter traffic disruption. Premixed type of fast-setting mortar should be poured without vibrator .

This method is similar for repair to girder and substructure, discussed in separate sections in this manual. It is expected to be effective in condition where the structure is subjected to repeated loadings.

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4-8-3 Work Sequence

(1) Removal of Deck Slab Concrete

Concrete surface are cut by saw, forming vertical edges, and then removed using breaker and chisel. Rebar 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.

(2) Setting of Formworks

Soffit formwork for re-casting deck slab must be very rigid and well-supported to prevent the fast-setting mortar from sagging due to its own weight.

(3) Addition of Longitudinal/Transverse Rebar

Longitudinal and transverse rebar to be provided shall be of same or bigger diameter than the existing, considering the current loading condition.

Spacing of rebar should be less than 150mm for durability and to avoid occurrence of bending cracks. Length of rebar should be around 1.4m for sufficient connection of each deck slab. For instance, if diameter of additional rebar to be used is 16mm, length of overlapping should be secured 640mm (16mm × 40 times) on each deck slab.

Additional rebar of transverse direction should be connected by rebar coupler. The end of the transverse rebar should be threaded for connection of coupler. The new rebar shall be tied to the existing bars using tie wires or by welding.

(4) Clean Up Inside Form

After placement of additional rebars and form work is completed, clean up inside form using vacuum cleaner.

(5) Apply Epoxy Resin to Existing Concrete Surface for Proper Bonding to Fast-setting Mortar

Epoxy resin shall be applied for all exposed section of existing concrete. Fast-setting mortar shall be poured within hardening time of epoxy resin.

(6) Keep the Form in Wet Condition

After cleaning inside form, water should be spread to keep wet condition prior to placing mortar.

(7) Mix with Water

The material consists of special cement of pre-mixed type and sand for fast setting and non shrink performance. One (1) bag of material which weighs 25kg and 4.5 liters water shall be mixed by steel-bladed electric mixer. One (1) bag of mixing will produce 13 liters of fast-setting mortar. Minimum mixing time shall be 2 minutes.

(8) Pour from Lower Side to Upper Position

Fast setting mortar is very flowable. Vibrator should not be used for spreading. ASequence of placing should be started from lower position to upper position in one direction. If a mass of mortar like lump is found during placing the mortar, it should be immediately remixed. It is a sign of insufficient mixing.

(9) Finishing of Surface, Curing

After placing 1m length of fast-setting mortar, finishing of surface should be started..

Finish unformed surfaces by broom, wood float, or steel trowel to match the adjacent existing concrete.

Continuous water curing with wetted cotton mat is always preferable to slow down drying. Curing should be started within two hours after beginning of placing mortar because fast setting mortar is non-shrink and non-bleeding type.

4-8-4 Required Materials and Tools/Equipment

4-8-4-1 Required Material

- Premixed type fast setting mortar
- Clean water
- Epoxy Resin (Bonding Coat to Concrete)
- Special anti-corrosion paint/Zinc-rich Primer (Bonding Coat to Rebar)

4-8-4-2 Required Equipment/Tools

- Sawing Equipment
- High Pressure Water Blaster
- Handy Concrete Breaker or Jackhammer
- Handy Power Chisel
- Electric Mixer with steel blade
- Water container
- Generator
- Hydraulic Pump system
- Brush

4-8-5 Specification

4-8-5-1 Material Requirement

Fast setting mortar shall conform to the requirements of the Specification as shown in Table 4-16 or equivalent ASTM Specification.

Table 4-16 Specification of Fast-Setting Mortar

Property	Test Method	Unit	Specifications
Compressive Strength (fc)	ASTM C-39 or JHS312	N/mm2 or MPa	1 day: fc ≥ 20 3 days: fc ≥ 30 7 days: fc ≥ 40 28 days: fc ≥ 50
Expansion Rate	ASTM C827	%	0 ~ +1%
Bleeding Rate	ASTM C940 or JHS312	%	0
Consistency	JHS312	Sec	6 ~ 10

Consistency shall be checked by J14 funnel test, if materials shall be applied by hydraulic pump. The material shall be approved by the Engineer through mill certificate of the supplier.

4-8-5-2 Construction Requirement

The Contractor shall submit shop drawings for the fast-setting mortar application to the Engineer for his review and approval.

The performance test for fast-setting mortar shall be applied by contractor to be approved by the Engineer.

4-8-6 Measurement and Payment

4-8-6-1 Basis of Measurement

Fast-setting mortar for continued deck slab performed in accordance with the plans and the specification 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 rebar will be in accordance with the DPWH Standard Specifications.

4-8-6-2 Basis of Payment

The quantity, measured as prescribed above, shall be paid for at a contract unit price. Removal and disposal of existing rebar and furnishing and installing new rebar and couplers will be paid for as specified in the corresponding DPWH Standard Specifications. 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.

4-9 PROTECTIVE MORTAR

4-9-1 Description of Repair Method

If the bridge is located less than 1km from coastal area, concrete member will be deteriorated due to salt attack. As explained in Section 3-2-2, it is recommended to apply protective mortar as preventive maintenance.

Protective mortar is made from polymer cement with lithium nitrate which is effective against chloride ions.

After or during application of appropriate repair method, protective mortar shall be applied to concrete member.

Photo 4-6 Protective Mortar applied on Deck Slab Bottom Surface

Photo 4-7 Protective Mortar applied on Patching Surface

4-9-2 Application Criteria

In application of repair method like patching, recasting and so on for deteriorated concrete member, location of bridge shall be considered. If the bridge is located less than one (1) km from coastal area, deterioration of concrete member by salt attack always occur. If defect of delamination and/or spalling is found, it is sign of salt attack.

There are two (2) thicknesses used in applying protective mortar. Apply 6mm thickness of protective mortar to surface of concrete member with severely deteriorated areas and/or repaired area. Apply 1mm thickness of protective mortar to surface of concrete member for preventive maintenance.

4-9-3 Work Sequence

(1) Surface Preparation

Entire surface of coating area should be cleaned by using cup wire brush and/or disc sander.

(2) Keep Dry Condition and Avoid Sunshine

Always stockpile PCM with Lithium Nitrite powder in dry condition and avoid sunshine or direct sunlight.

(3) Weigh PCM with Lithium Nitrite

PCM with Lithium consists of Lithium Nitrite and premix type non-shrink mortar. Measure one (1) kg of powder by digital weigh scale with less than one (1) gram margin of error.

(4) Weigh the Emulsion

Emulsion consist of Lithium Nitrite and adhesive. Measurements shall be kept accurate by digital weigh scale with less than one (1) gram margin of error.

(5) Mix Powder and Emulsion

One (1) kg of powder and 180g of emulsion shall be mixed by hand. Use rubber gloves. During mixing, do not add water.

(6) Application of PCM with Lithium Nitrite

Apply and spread PCM with Lithium Nitrite on surface to be patched using trowel and/or brush.

(7) Curing of PCM with Lithium Nitrite

Spray water on patched surface for 3 days continously.

4-9-4 Required Materials and Tools/Equipment

4-9-4-1 Required Material

- Polymer cement powder with lithium nitrite
- Emulsion made of lithium nitrite and adhesive

4-9-4-2 Required Equipment/Tools

- Power disk grinder/cutter
- Portable generator
- Trowel
- Brush/Roller

4-9-5 Specification

4-9-5-1 Material Requirement

Protective mortar by PCM with Lithium Nitrite shall conform to the requirements of the Specification as shown in Table 4-17 or equivalent ASTM Specification.

Table 4-17 Specification of PCM with Lithium Nitrite

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM C-39 or JHS416	N/mm2	28 days ≥ 33
Bonding strength to concrete	JHS416	N/mm2	2.0 (wet condition)
Bleeding Rate	ASTM C940 or JHS416	%	0.04
Consistency	JHS416	Sec	6~10
Finishing appearance			Homogeneous appearance
Workability			No hanging, shearing, peeling- off and bulging

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

4-9-5-2 Construction Requirement

(1) Surface Preparation of Concrete

If the concrete member will be applied appropriate repair method, objective portion shall be chipped off deteriorated concrete area by drill and hammer.

(2) Material Handling

Material of protective mortar shall be kept in good condition (dry and away from sunlight). When powder and emulsion are mixed, never add water.

(3) Application of Protective Mortar

Protective mortar of 1mm thickness shall be applied on surface of concrete except at areas requiring 6mm thickness. Protective mortar of 6mm thickness shall be applied on the surface if deterioration is in severe condition. Also, if it is necessary to chip-off defective portion on the concrete member, protective mortar of 6mm thickness shall be applied to the surface prior to repair of defective portion.

(4) Quality Control and Inspection

The contractor shall conduct a quality control program that includes, but 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 protective mortar application.
- Inspection of all work in progress to ensure work is being done is in accordance with DPWH Standard Specifications, and approved manufacturer's instructions.
- Inspection of all work completed including verification of all repairs for objective surface.

4-9-6 Measurement and Payment

4-9-6-1 Basis of Measurement

The method of measurement to determine payment for protective mortar shall be based on the total applied area, as identified by the Engineer.

4-9-6-2 Basis of Payment

The contract price paid per square 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 of surface cleaning, completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

4-10 PROTECTIVE COATING

4-10-1 Description of Repair Method

If the bridge is located more than 1km from coastal area, concrete member will be deteriorated due to carbonation. As discussed in Section 3-2-2, it is recommended that protective coating should be applied as preventive maintenance.

Protective coating is made from acryl urethane based coating which is effective against Carbon dioxide, weather/UV rays, chemical and oil damage.

After repairing damage, protective coating shall be applied on the concrete member.

Photo 4.8 – Protective Coating applied on Deck Slab Bottom Surface

4-10-2 Application Criteria

Protective coating shall be applied to surface of concrete member for preventive maintenance.

Material is an acryl urethane based coating characterized by weather / UV resistance, chemical and oil resistance needed for the protection of concrete and steel structures. The Base Resin and Hardener are mixed at a ratio by weight of 4: 1, respectively. Coating is normally applied for 1 to 3 coats.

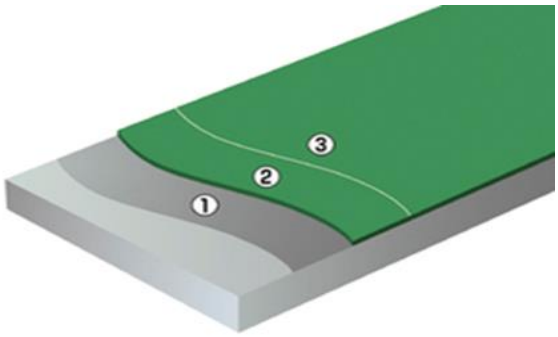
4-10-3 Work Sequence

(1) Surface Preparation

Entire surface of coating area should be cleaned by using cup wire brush and/or disc sander

(2) Mixing Acryl Urethane Protective Coating Materials

Acryl urethane based coating is characterized by its resistance to weather/UV, chemicals and oil necessary for the protection of steel and concrete structures. The Base Resin and Hardener are mixed at a ratio by weight of 4: 1, respectively.



(3) Application of Protective Coating

Acryl Urethane Protective Coating is applied by roller and/or brush on surface to be coated. Interval time between application of first layer and second layer is minimum 3 hours for next coating. Coating is normally applied for 1 to 3 coats.

.

4-10-4 Required Materials and Tools/Equipment

4-10-4-1 Required Material

- Base Resin 16 Kg (Tin Can)
- Hardener 4 Kg (Tin Can)

4-10-4-2 Required Equipment/Tools

- Power Disc Grinder/Cutter
- Portable Generator
- Paint Roller and Paint Brush

4-10-5 Specification

4-10-5-1 Material Requirement

Acryl Urethane Protective Coating shall confirm to the requirements of the Specification as shown in Table 4-18 or equivalent ASTM Specification.

Table 4-18 Specification of Protective Coating

Property	Test Method	Unit	Specifications
Bond Strength	ASTM D3359 or ASTM D7234	N/mm2	≧1.5
Tap Water Resistance	ASTM D6943	-	No Change
Acid Resistance(5%H_2SO_4)	ASTM D6943	-	No Change
Alkali Resistance(5%NaOH)	ASTM D6943	-	No Change

The material shall undergo quality tests and confirm to the above specifications

4-10-5-2 Construction Requirement

(1) Surface Preparation of Concrete

After appropriate repair method is selected, surface preparation shall be conducted by electric disc grinder and/or brush.

(2) Material Handling

After mixing base resin and hardener, protective coating shall be applied to the surface within hardening time of about 3 hours.

(3) Application of Protective Coating

Apply 1 to 3 coats coating

(4) Quality Control and Inspection

The contractor shall conduct a quality control program that includes, but 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 shall be carried out prior to protective coating application.
- Inspection of all work in progress to ensure work is being done is in accordance with DPWH Standard Specifications and manufacturer's instructions.
- Inspection of all completed work including verification of all repairs for coated surface.

4-10-6 Measurement and Payment

4-10-6-1 Basis of Measurement

The method of measurement to determine payment for protective coating shall be based on the total applied area, as identified by the Engineer.

4-10-6-2 Basis of Payment

The quantity, measured as prescribed above, shall 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 protective coating.

CHAPTER 5 REPAIR OF CONCRETE BRIDGE SUPERSTRUCTURE

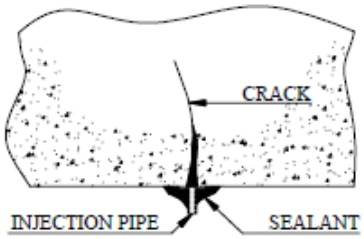
5-1 EPOXY INJECTION

5-1-1 Description of Repair Method

This method involves crack repairs to concrete structures, particularly to deck slab as shown in Figure 5-1. The works include preparation of concrete surface, insertion of pipe fittings bonded with adhesive, injection of epoxy, curing and conducting performance test.

Epoxy injection for concrete cracks requires highly skilled process and its effectiveness depends mostly on the proficiency of the certified applicator. Said person should be qualified based on his previous work records, and approved by the Engineer.

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



(After Injection)

Figure 5-1 Crack Injection Method

5-1-2 Application Criteria

Epoxy injection is used to restore structural soundness of structures exhibiting inactive cracks. Cracks with more than 0.3 mm up to 3.0 mm widths can be bonded and sealed by injecting low-viscosity epoxy.

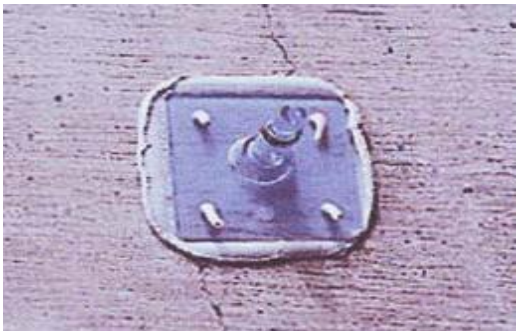
5-1-3 Work Sequence

(1) Cleaning of Cracks.

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

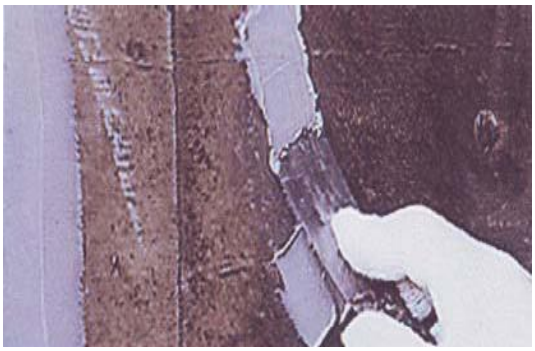
(2) Bonding of Fitting Pipe

Pipe fittings are bonded with the adhesive to the crack center for injecting epoxy. Spacing of the pipes varies between 150 mm 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.



(3) Sealing of Cracks at the Surface

Using a 5 cm width strap, epoxy sealant is applied on the area around the pipe fitting and cracks, allowing it to harden.



(4) Fitting of Injector

Connect the terminal of the injector to the pipe fittings.

(5) Injection of Epoxy

Epoxy shall be injected using air-activated epoxy injection guns as shown in Figure 5-2. Injection is performed on the pipe fitting. Duration of the injection operation shall be in accordance with the supplier's instruction.

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, epoxy injection is carried out from one end of the crack to the other, in a similar manner.

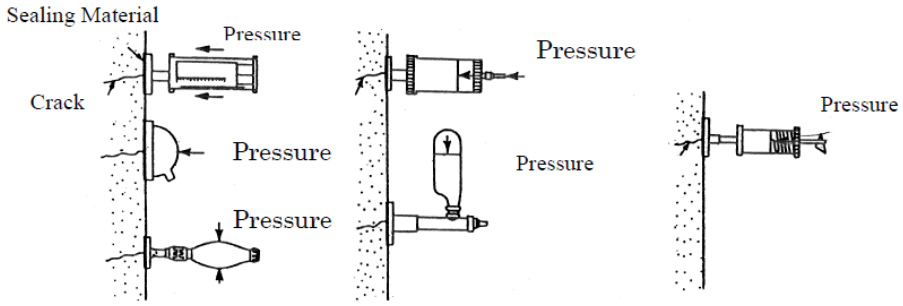


Figure 5-2 Crack Injection Method

(6) Curing of Injected Material

After the crack has been sealed, remove the projecting pipe fittings and fill holes with an epoxy patching compound. Surface coating will be applied, when required in the process

5-1-4 Required Materials and Tools/Equipment

5-1-4-1 Required Materials

- Epoxy Resin for Injection
- Epoxy Resin Adhesive
- Sealant (Epoxy Putty)
- Set of Injection Tool

5-1-4-2 Required Equipment/Tools

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

5-1-5 Specifications

5-1-5-1 Material Requirement

(1) Type-A (Epoxy Injection)

The epoxy injection material shall be compatible with the host concrete and shall have the properties as shown in Table 5-1. The testing of said properties shall be in accordance with the relevant standards shown in Table 5-2, or equivalent ASTM Specifications.

Table 5-1 Specifications of Epoxy Resin for Injection to Superstructure (1/2)

Property	Test Method	Unit	Specification
Viscosity	JIS K 6833/ASTM D2393	mPa-s	≤ 1000
Potlife	-	minute	60

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

Table 5-2 Specifications of Epoxy Resin for Injection to Superstructure (2/2)

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.15 ± 0.1
Compressive Strength	JIS K 7208/ASTM D695	N/mm^2	≥ 50
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 40
Tensile Shear Bond	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Slant Shear Bond Strength to Concrete	JIS K6852/ASTM C882	N/mm^2	15/above
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM D7234	N/mm^2	≥1.5 CF

The material shall be approved by the Engineer through mill certificate of the supplier. CF – Concrete Failure

(2) Sealant

The epoxy-based sealant material shall be compatible with the injection material and shall have the properties as listed in Table 5-3. The testing of materials shall be in accordance with the listed standards or equivalent ASTM Specifications.

Table 5-3 Specifications of Sealant (Putty) for Epoxy Injection to Superstructure

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.50±0.30
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	≥ 50
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 15
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM 7234	N/mm^2	≥ 1.5 CF

The material shall be approved by the Engineer through mill certificate of the supplier. CF – Concrete Failure

5-1-5-2 Construction Requirement

(1) Concrete Preparation

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 the drawings, as stated in the Bridge Inspection Manual of BMS. The detail of the quantities shall be marked out on the concrete elements, and confirmed by the designated Engineer prior to epoxy application. The Engineer may adjust the extent of the work as the project proceeds, based on actual conditions.

At loose or spalled areas of concrete, grease, oil or other contaminants shall be removed. If necessary, wire brushes, grinding wheels or power brush shall be used as cleaning devices. Loose or spalled areas of concrete, laitance, traces of paint or other coating materials within the marked out area shall be removed.

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 epoxy injection.

(2) Pipe Fitting Adhesion

The pipe fittings shall be fixed at 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. Mixed 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 newly injected cracks shall be allowed to cure for at least 12 hours.

(3) Epoxy Injection

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, approved by the Engineer. Before the works commence, the Contractor should ensure that all necessary tools and equipment are on site.

The materials shall be used when the ambient temperature is below or at 5^{O}C or on a falling thermometer, or is above 35^{O}C, without the Engineer's approval. The injection resin shall be of a pre-packed type and only complete set will be allowed for use. No part packs or on-site batching will be allowed under any circumstances. In all operations of storage, mixing and application, the Contractor is to comply with the health and safety regulations of the Engineer and the relevant governing authorities.

(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.

(5) Performance Test

Low Frequency Pulse Velocity Ultrasonic Inspection will be determined if the epoxy resin has penetrated to the full depth of the crack. If incomplete penetration is revealed by inspection, such conditions shall be reworked at the Contractor's expense.

5-1-6 Method of Measurement and Payment

5-1-6-1 Method of Measurement

The payment for the epoxy injection works on cracks shall be based on the total length of the cracks, as identified by the Engineer.

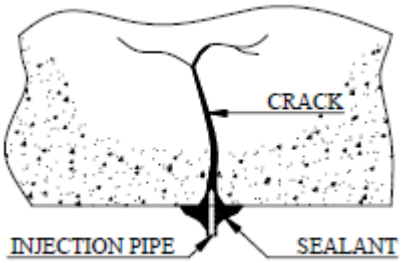
5-1-6-2 Basis of Payment

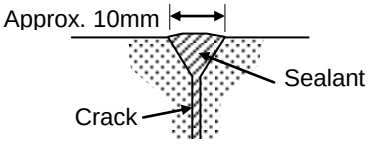
The contract price paid per meter for this work item shall include full compensation for supplying all labor, materials, tools, equipment, and contingencies, and for performing all the works. This includes activities in the preparation and injection of epoxy on cracks in the existing concrete, completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

5-2 CAULKING

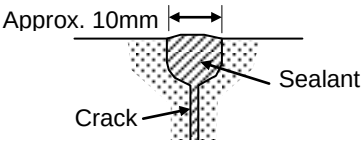
5-2-1 Description of Repair Method

Active cracks are treated and repaired with flexible sealants as shown in Figure 5-3. 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.





(V-Type)



(U-Type)

Figure 5-3 Types of Caulking

5-2-2 Application Criteria

Crack widths could be more than 3.0 mm with depth of less than 300 mm. In this case, the top surface edges should be chipped or sawn to form a V-type or U-type groove, in order to provide a caulking for inlet of gravity flow of resin into the crack by injection pump.

Cracks wider than 3.0 mm generally require epoxy based injection material (mix of epoxy and mineral filler).

5-2-3 Work Sequence

(1) Cleaning of the cracks.

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. Remove the residual water or solvent in the crack with filtered (dust and oil free) compressed air and allow adequate time for drying.

(2) Preparation of Caulking

Using a concrete saw, hand tools or pneumatic tools, a V-groove or U-groove, approximately 10 mm in width and in depth, is prepared at the surface along the crack. The groove shall then be partially sealed with a sealant.

(3) Drilling Holes and Fixing the Injection Pipes

Port holes are drilled near the crack, or in the groove. Injection pipes are then fixed at the tip of the groove. Spacing between ports varies between 150 mm to 500 mm, generally depending on the width and depth of the cracks.

The groove is then completely sealed with sealant.

(4) Injecting Epoxy Grout

Epoxy grout can be injected using injection pumps, or air-activated caulking guns. The duration of injection process shall be in accordance with the supplier's instructions.

For horizontal cracks, the injection is carried out from the injection pipe at end of the crack to the other end.

(5) Curing of Injected Material

After the crack is sealed, the projecting injection pipes are cut and the holes are filled with epoxy patching compound. If surface coating or carbon fiber sheet will be applied, the portion with sealant and tip of the cut pipe should be grinded to form a smooth surface.

5-2-4 Required Materials and Tools/Equipment

5-2-4-1 Required Materials

- Epoxy Grout
- Sealant

5-2-4-2 Required Equipment and Tools

- Epoxy Injection Pump
- Power Disc Grinder
- Portable Generator
- Brush
- Set of Injection Tools

5-2-5 Specifications

5-2-5-1 Material Requirement

(1) Epoxy Grout

The epoxy grout material shall be compatible with the host concrete and shall have the properties listed in Table 5-4. The testing of materials shall be in accordance with the relevant standards or equivalent ASTM Specifications.

Table 5-4 Specifications of Epoxy-Based Injection Material to Girder

Property	**Test Method**	**Unit**	**Specification**
Viscosity	JIS K 6833/ASTM D2393	mPa-s*	≤ 1000
Pot life	-	minute	60
Specific Gravity	JIS K 7112/ASTM D792	-	1.15 ± 0.10
Compressive Strength	JIS K 7208/ASTM D695	N/mm^2	≥ 50
Modulus of Elasticity	JIS K 7208/ASTM D695M	N/mm^2	≥ 1000
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 40
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM D7234	N/mm^2	≥ 1.5 CF

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

CF – Concrete Failure

(2) Sealant

The epoxy-based sealant material shall be compatible with the injection material and shall have the properties listed in Table 5-5. The testing of materials shall be in accordance with the relevant standards as shown or equivalent ASTM Specification.

Table 5-5 Specifications of Epoxy-Based Sealant to Girder

Property	**Test Method**	**Unit**	**Specification**
Specific Gravity	JIS K 7112/ASTM D792	-	1.50±0.30
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	≥ 50
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 15
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Bond Strength to Concrete (Dry/Wet)	JIS K 5400/ASTM D 7234	N/mm^2	≥ 1.5 CF

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

CF – Concrete Failure

5-2-5-2 Construction Requirement

(1) Preparation of Concrete

The intention of this work is to fill and seal the cracks, particularly those found on concrete bridges. The extent of the cracks shall be indicated by the Contractor and shown on

the drawings, as stated in the Bridge Inspection Manual of BMS. The detail of the quantities shall be marked out on the concrete elements, and confirmed by the designated Engineer prior to epoxy application The Engineer may adjust the extent of the work as the project proceeds, based on actual conditions.

At loose or spalled areas of concrete, grease, oil or other contaminants shall be removed. If necessary, wire brushes, grinding wheels or power brush shall be used as cleaning devices. Loose or spalled areas of concrete, laitance, traces of paint or other coating materials within the marked out area shall be removed.

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 for Caulking

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 4.2.1, at the surface along the crack. Clean the groove with an oil free air jet or wire brush and allow drying completely before placing the sealant. The sealant shall be applied in accordance with the manufacturer's instructions.

(3) Drilling Holes and Fixing Injection Pipes

The injection pipes shall be fixed at intervals along the direction of each crack. The distance between each pipe shall be shown on drawings considering the width and the depth of crack, for approval by the Engineer. The 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. Mixing is continued until a uniform paste is obtained.

Holes for injection pipes are drilled near the crack or in the groove until the tip of holes reach the full depth of the crack. The injection pipes are inserted into the holes and fixed with epoxy adhesive. The mixed sealant shall be applied into the groove along the cracks as a caulking. A complete seal shall be made around the metal bases of each port. The applied mixed sealant shall be allowed to cure for at least 12 hours.

(4) Grout Injection

Each crack shall be treated in a single, continuous operation. Sufficient grout material shall therefore be readily available prior to the commencement of the works.

The grout 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 Contactor shall propose suitable grout material based on the study on the crack movement, subject to Engineer’s approval.

The preparation, mixing and application of the grout materials shall be undertaken in strict compliance with the manufacturer’s recommendations. The Contractor has to ensure that all necessary tools and equipment are on site until the works commence.

The injection resin shall be of a pre-packed type and only the use of full units will be allowed. No partial 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 recommendations of the Engineer and the relevant regulations.

(5) Curing

The grout shall be allowed to cure for twenty four (24) hours and shall be left undisturbed during this time. The injection pipes are cut after confirmation of hardening. Cut the tip of injection pipe and the surface of sealant shall be smoothened for the succeeding works.

(6) Performance Test

Conduct Low Frequency Ultrasonic Pulse Velocity Test to determine if the epoxy resin has penetrated the root of the crack. If incomplete penetration is revealed by the test, the Contractor shall redo the work, at his own expense.

5-2-6 Measurement and Payment

5-2-6-1 Method of Measurement

The payment for the caulking shall be based on the total length of the cracks, to be determined by the Engineer.

5-2-6-2 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 in performing all the works involving the preparation and injection of epoxy on cracks, completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

5-3 PATCHING

5-3-1 Description of Repair Method

Patch repair is performed to restore small areas where concrete is damaged by spalling, scaling and impact. This method of repair is generally applied using trowel and require none or minimum formworks. The patch thickness is limited to a maximum of 100 mm depth of hollow surface.

Type A Patching is for used for defects without exposed rebar while Type B Patching is applied to surfaces with exposed rebar.

Patch repairs may be composed of Portland cement mortars or non-shrinkage cement mortar, depending on the type of patching, location and extent of damage.

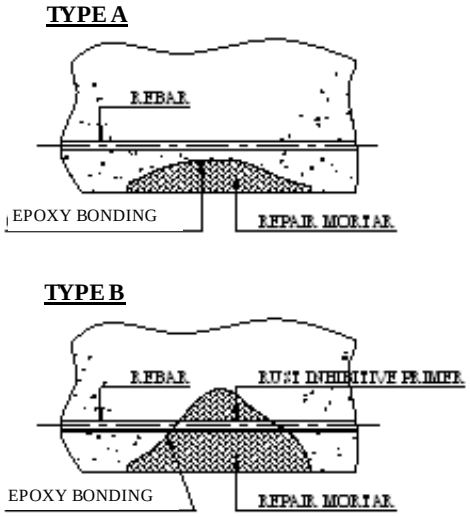


Figure 5-4 Types of Patching

5-3-2 Application Criteria

Patch repair is classified into two types as shown in Figure 5-4, considering defective area and surface. Type-A is applicable to surfaces without exposed rebar, having defective widths of up to 300 mm and depths of up to 50 mm. Meanwhile, Type B is used for surfaces with exposed rebar, with defective widths between 300 mm and 600 mm, and up to 100 mm depths.

Portland cement mortar and polymer cement mortar is used for Type-A and Type-B patching, respectively.

5-3-3 Work Sequence

(1) Removal of Defective Concrete

Remove all defective, unsound and contaminated concrete and prepare the edges for the patch area. If local corrosion in reinforcement with section loss is found, which would require additional bars, remove only the damaged area of concrete including the length needed to bond the new reinforcement as shown in Figure 5-5.

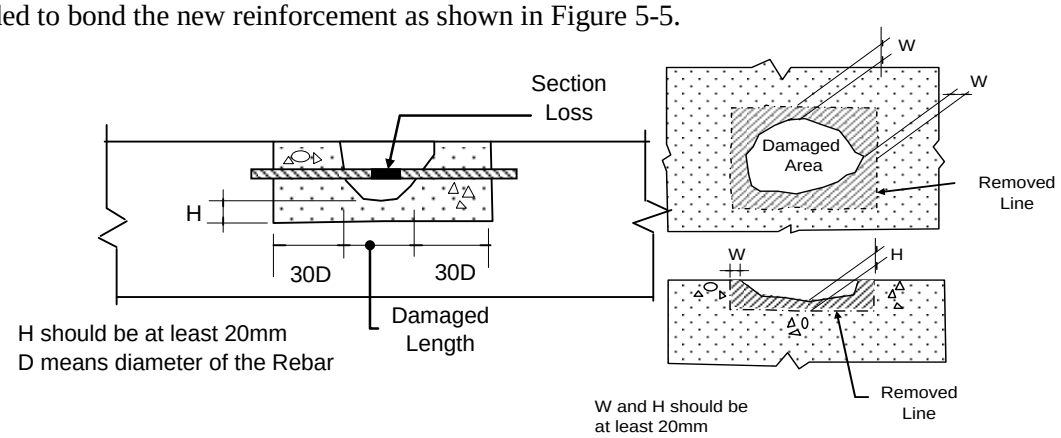


Figure 5-5 Limits of Removal of Damaged Concrete

(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. Corrosion must be removed before placing the new concrete. If deterioration is due to chloride contamination or if the reinforcement is covered with loose corrosive elements and has developed pits, use water abrasive blasting until all the rust are removed.

(3) Applying Bonding Coats to Concrete and Rebar

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

(4) Placing of Mortar

The mortar should be placed in layers of about 20 mm thick. 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.

Patching to the surrounding concrete is performed using a form material, and then hammered using a mallet, wood or steel trowel.

(5) Curing

All types of cement repairs need thorough and continuous curing to develop the desirable strength and impermeability, and to minimize drying shrinkage while bond strength is developing.

5-3-4 Required Materials and Tools/Equipment

5-3-4-1 Required Materials

Portland Cement Mortar	**Polymer Cement Mortar (PCM)**
- Portland Cement	- PCM Powder
- Sand	- PCM Emulsion
- Water	- Concrete Nail
- Concrete Nail	- Bonding Agent to Concrete (Epoxy Bonding)
- Bonding Agent to Concrete (Epoxy Bonding)	

5-3-4-2 Required Equipment

- Chisel
- Portable Generator
- Wire Brush
- Small Hammer
- Mortar Mix Bucket
- Safety goggles
- Trowel
- Dust mask

5-3-5 Specifications

5-3-5-1 Material Requirement

Portland Cement Mortar shall conform to the requirements of Item 405, Structural Concrete, DPWH Standard Specifications. Strength test for Portland cement mortar shall be based on ASTM C 780

The polymer cement mortar shall conform to the requirements of the specifications shown in Table 5-6 or equivalent ASTM Specification.

Table 5-6 Specifications of Polymer Cement Patching Material

Property	Test Method	Unit	Specification
Compressive Strength	JSH 416/ASTM C39	N/mm2	At 28 days: ≥ 25
Bonding Strength to Concrete	JHS 416/ASTM D 7234	N/mm2	≥ 1.5
Bleeding Rate	JHS 416/ASTM C 39	%	0

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

The epoxy bonding primer to concrete shall conform to the specifications shown in Table 5-7.

Table 5-7 Specifications of Bonding Primer to Concrete for Patching

Property	Test Method	Unit	Specifications
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	75
Flexural Strength	JIS K 6911/ASTM D790M	N/mm^2	40
Tensile Strength	JIS K 7113/ASTM D638M	N/mm^2	30
Tensile Shear Bond to Steel	JIS K 6850/ASTM D1002	N/mm^2	10
Slant Shear Bond to Mortar	JIS K6852/ASTM C882	N/mm^2	15

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

The zinc-rich primer to be applied to rebar shall be in accordance with the requirements of the specifications shown in Table 5-8.

Table 5-8 Specifications of Zinc-Rich Primer to be Applied to Rebar

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

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

5-3-5-2 Construction Requirement

(1) Removal of Damaged Concrete

Old concrete within the marked out areas shall be removed using light mechanical breakers or hammer and chisel. Cut the exposed reinforcement and determine soundness concrete substrate to the satisfaction of the Engineer, without breaking the concrete behind the reinforcement.

(2) Preparation of Concrete Surface

All concrete surfaces that are to receive repair mortar shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss, and then coated with bonding primer. Care shall be taken to ensure that vibration from the method of preparation does not cause delamination of adjacent materials or concrete.

(3) Additional Concrete Breakout

Where the breakout indicates that the exposed reinforcement is further corroded or the surrounding concrete is not sound, the Contractor shall be informed and an enlarged area is agreed to the satisfaction of the Engineer.

The Contractor shall test the concrete for depth 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 order to remove all carbonated concrete. The additional concrete breakout shall not extend to more than 20 mm behind the bottom layer main reinforcement. During breakout, care shall be taken to minimize damage to existing reinforcement.

(4) Additional or Replacement of Rebar

The Contractor shall report to the Engineer any rebar that has 10% or more section loss as a result of corrosion. Additional or replacement of rebar shall be provided as instructed by the Engineer. The new rebar shall be cleaned to the same standard as the existing rebar and shall be lapped on the side of the existing bars and 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 then applied with zinc rich primer to prevent further corrosion. The Contractor shall obtain Engineer's approval for the rebar prior to proceeding with repair mortar application.

(5) Method of Placing Mortar

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. The textured finish of the final repair mortar layer shall match the finish on the existing interior surface.

The 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. 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.

(6) Curing

Curing of the repair mortar shall be in accordance with the instructions of the polymer-modified additive manufacturer. 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.

5-3-6 Measurement and Payment

5-3-6-1 Method of Measurement

The Engineer shall measure the area prepared for patching by square meter after the identified thickness of surface has been removed. The measured pay quantity will be those areas verified by the Engineer and satisfactorily completed.

5-3-6-2 Basis of Payment

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

5-4 RECASTING CONCRETE/GROUT

5-4-1 Description of Repair Method

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 5-6. If concrete placing by vibration is often a problem, grout and free flowing self-compacting concrete should be used to minimize the vibration required.

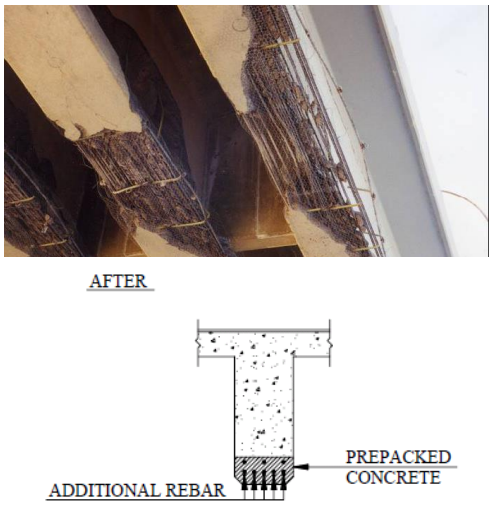


Figure 5-6 General View of Recasting

5-4-2 Application Criteria

Recasting Concrete/Grout is divided into two methods namely, concrete placing and mortar grouting types. Further, the mortar grouting type has two categories depending on materials used, i.e., Portland cement and non-shrink cement.

Considering the position and scale of damage defined in Figure 5-7, the application of the recasting concrete and grout are classified according to the formwork types, such as the “Envelope Type” and “Mail Box Type,” shown in Figure 5-8. Envelope type formwork is open at the top for pouring concrete while the mail box type formwork consists of holes or slit at its side for purposes of grouting or pumping mortar. Mail box type formwork is further classified based on concrete volume, applied area and rebars arrangement as shown in Figure 5-7, with due consideration to cost performance.

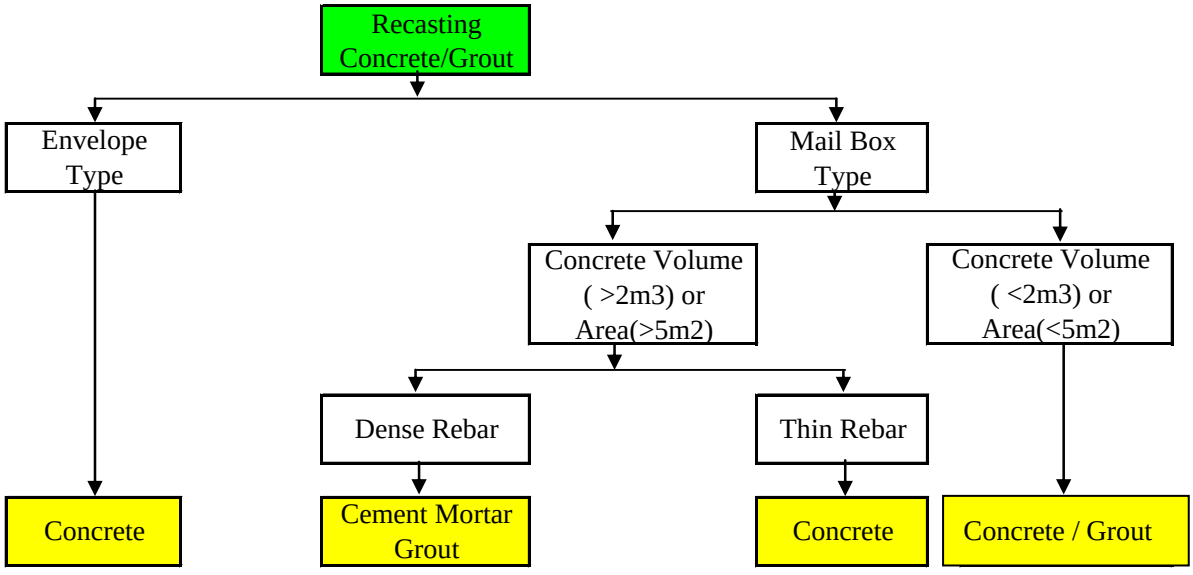
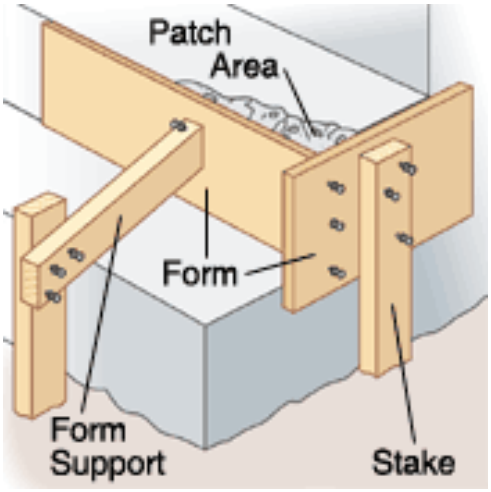
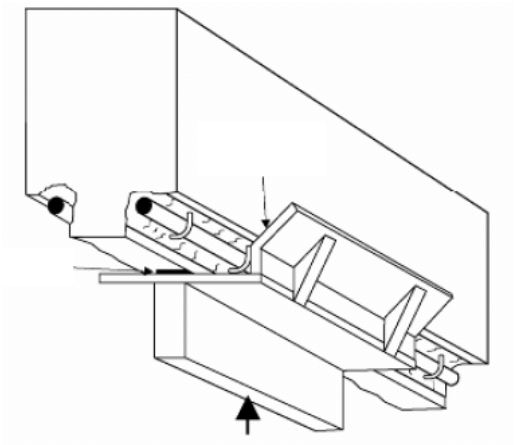


Figure 5-7 Flowchart of Selecting Material for Recasting



Envelope Type



Mail Box Type

Figure 5-8 Type of Formwork of Recasting

5-4-3 Work Sequence

The work sequence of concrete mixing, pouring and curing is in accordance with Section 4-6-3 and 4-6-5 of "PARTIAL DECK SLAB REPLACEMENT". The following work sequence is only for cement mortar grout .

(1) Removal of Girder Concrete

All deteriorated or damaged concrete are cut using saw to form the vertical edges, and then removed using a breaker and chisel. Rebars are examined for loss of section due to corrosion. If cross sectional area of the reinforcement has been reduced by more than 15%, provide extra reinforcements, as necessary.

(2) Preparation of Old Concrete and Rebar

A suitable bonding agent for concrete and reinforcement should be selected taking into consideration limited working time available for fixing the formwork and placing the new concrete. Concrete should be placed immediately after applying bonding coat to the faces of old concrete and anti-corrosion primer to rebars.

(3) Cutting of Deteriorated Rebar and Adding New Rebar

Deteriorated old rebar are cut up to the required lap length. New bars to be provided shall be of same or bigger diameter than the existing, considering the current loading condition. The lap length is calculated as 30 times the new rebar diameter. The new rebar shall be tied to the existing bars using tie wires or by welding.

(4) Setting Formworks

Formwork for re-casting the girder must be very rigid and well-supported to prevent the new concrete from sagging to the old concrete due to its own weight.

(5) Mixing of Mortar

Cement mortar grout shall be composed of one part cement, three parts sand, and a minimum amount of water necessary for the mixture to flow under its own weight, and then mixed using a grout mixer.

(6) Mortar Grouting

The mortar has to be carefully placed to avoid the entrapment of air. Pumping is usually employed for the mail box type formwork which can be used for smaller pours. When pumping is used, the delivery hose should be at a low position while pouring, to allow the air to be displaced.

(7) Curing and Removal of Formworks

Continuous water curing by spraying 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.

5-4-4 Required Materials and Tools/Equipment

5-4-4-1 Required Materials

For Concrete

- Portland Cement
- Silica fume
- Aggregate/Sand
- Rebar (Reinforcing bar, Grade 60)
- Bonding Coat to Concrete (Epoxy Resin Adhesive)
- Anti-corrosion Primer to Rebar (Zinc Rich Primer)
- Cotton mat (Curing)

For Mortar

- Portland Cement (Cement Mortar)
- Admixture for consistency
- Reinforcing steel bar
- Bonding Coat to Concrete (Epoxy Resin Adhesive)
- Anti-corrosion Primer to Rebar (Zinc Rich Primer)

5-4-4-2 Required Tools/Equipment

- 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

5-4-5 Specifications

5-4-5-1 Material Requirement

(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 meter of concrete and would be fully accommodated in a small mixer.

1) Cement
   - Portland cement 13.0 kg
   - Silica fume 0.5 kg (If silica fume is unavailable, use 13.5kg cement)

2) 10mm Crushed Aggregate 36.0 kg

3) Sand (assumed with 2% water content) 18.5 kg

4) Water (maximum) 5.4 liters

5) Super plasticizer (nominal) 25ml

The epoxy bonding primer to concrete shall conform to the specifications shown in Table 5-9.

Table 5-9 Specification of Epoxy Bonding Primer to Concrete for Recasting

Property	Test Method	Unit	Specifications
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	70
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	40
Tensile Strength	JIS K 7113/ASTM D638M	N/mm^2	30
Tensile Shear Bond to Steel	JIS K 6850/ASTM D1002	N/mm^2	10
Slant Shear Bond to Mortar	JIS K6852/ASTM C882	N/mm^2	15

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

The zinc-rich primer applied to rebar shall be in accordance with the specifications shown in Table 5-10, or equivalent ASTM Specifications.

Table 5-10 Specification of Zinc-Rich Primer to Rebar for Recasting

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

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

5-4-5-2 Construction Requirement

(1) Removal of 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 deep around the perimeter to be replaced. Girder concrete is removed by breaker and portable electric chisel near the vertical edges.

(2) Preparation of Concrete and Rebar Surface

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. Using a brush, the bond coat shall be applied to the exposed concrete surface and exposed reinforcement. The subsequent repair material shall be applied while the bond coat is still wet or tacky.

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.

(3) Adding Rebar

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

Tying of loose bars will be required. Rebar which have been cut or have lost 25 percent or more of their original cross sectional area shall be supplemented with new reinforcement bars. New bars shall be lapped with a minimum of 30 bar diameters to existing bars. An approved mechanical bar splice capable of developing in tension at least 125 percent of the yield strength of the existing bar shall be used when it is not feasible to provide the minimum bar lapping. No welding of bars will be permitted.

(4) Setting Formwork

The Contractor shall submit the shop drawings of the formwork of recasting concrete prior to the commencement of the repair works for the Engineer’s approval. The formwork for re-casting 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 pumped 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 used should be compatible with the repair materials, particularly epoxy based and latex modified concrete and grouts.

(5) Mixing and Placing Mortar

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.

All large damaged areas shall be re-cast to accurately restore the original face of the girder. 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 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.

5-4-6 Measurement and Payment

5-4-6-1 Basis of Measurement

Recasting concrete/grout 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 will be made for rebar will be in accordance with the DPWH Standard Specifications.

5-4-6-2 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 for as specified in the DPWH Standard Specifications. 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.

5-5 CARBON FIBER SHEET/PLATE BONDING TO CONCRETE GIRDER

5-5-1 Description of Repair Method

Carbon fiber sheet/plate for reinforced repair and strengthening systems are combination of carbon fiber sheet/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 5-9. 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.

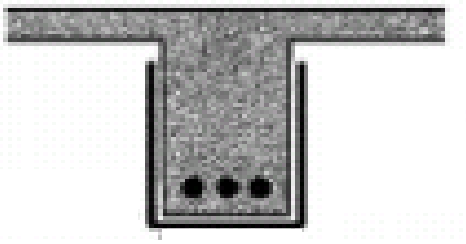


Figure 5-9 Carbon Fiber Sheet/Plate Bonding

5-5-2 Application Criteria

The first system for concrete girder shall generally consist of woven carbon fiber sheet (CFS) reinforcing layers bonded to the concrete surface with epoxy. The second system shall generally consist of carbon fiber plate (CFP) bonded to the concrete with epoxy.

As shown in Figure 5-10, the section of 1/4 in span from both ends is applied with CFS as protection against shear cracks (Photo 5-1) while the center section of 1/2 in span is applied with CFP for protection against flexural cracks (Photo 5-2) caused by live load.

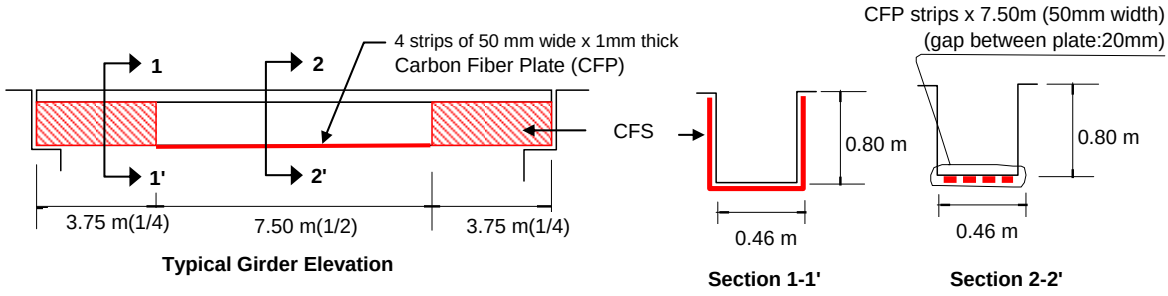


Figure 5-10 Arrangement of Carbon Fiber Sheet/Plate (For Reference)

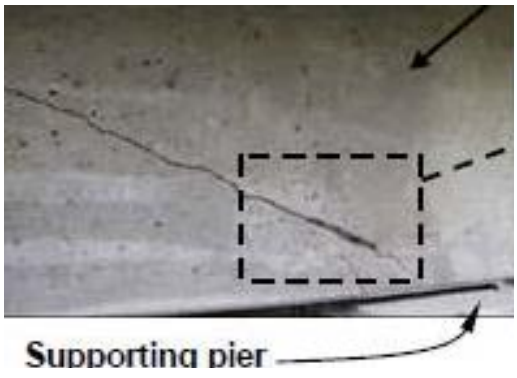


Photo 5-1 Shear Cracks at Both Ends

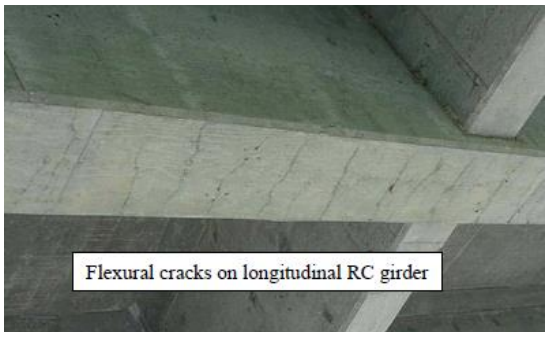


Photo 5-2 Flexural Cracks at the Center Portion

5-5-3 Work Sequence

5-5-3-1 For CFS

(1) Preparation of Concrete

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.

(2) Application of Primer

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

(3) Adjustment of Unevenness with Putty

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

(4) 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 permeating into the CFS.

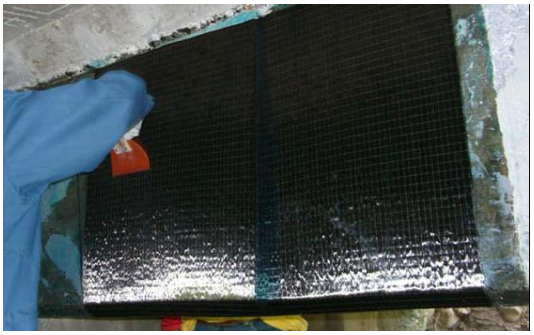
(5) Installation of CFS (1st layer)

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

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

(6) Squeezing Out of Entrapped Air

For complete fusion, entrapped air is squeezed out of the carbon sheets using a roller, before applying the adhesive sets.



(7) Over Coating Resin Application

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

(8) Installation of CFS (2nd layer)

Properly aligned CFS strips (2nd layer) are installed to the resin over coated surface to further strengthen the section.

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

(9) Surface Protection

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

5-5-3-2 For CFP

(1) Preparation of Concrete

Disc grinder or abrasive sandblasting is used to clean the concrete and to ensure that concrete surface is even and smooth.

(2) Application of Primer

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

(3) Adjustment of Unevenness with Putty

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

(4) 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 center and 1 mm on the edges.

(5) Installation of 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.

(6) Squeezing Out of Entrapped Air

For complete impregnation, entrapped air is squeezed out the CFP using a roller, before applying the adhesive sets.

(7) Pressure Attachment of CFP

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

5-5-4 Required Materials and Tools/Equipment

5-5-4-1 Required Material

Carbon Fiber Products

- Carbon fiber sheet
- Carbon fiber sheet Strip
- Carbon fiber Plate

Epoxy Materials

- Epoxy primer
- Epoxy putty
- Epoxy resin

5-5-4-2 Required Equipment

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

5-5-5 Specifications

5-5-5-1 Material Requirement

The CFS shall conform to the specification shown in Table 5-11.

Table 5-11 Specifications of CFS to Concrete Girder

Property	Test Method	Unit	Specifications
Carbon fiber sheet weight	JIS K7071	g/m2	200
Tensile Strength	JIS K 7073/ASTM D3039	N/mm^2	$\geq$ 3400
Overlap Tensile Strength	JIS K 7073/ASTM D3039	N/mm^2	$\geq$ 3400
Tensile Bond Strength to Concrete (Dry/Wet)	JIS K5400/ASTM D7234	N/mm^2	$\geq$ 1.5 CF

The material test shall be applied tensile strength test for CFS to be approved by the Engineer. CF – Concrete Failure

The CFP shall conform to the specification shown in Table 5-12 or equivalent ASTM Specifications.

Table 5-12 Specifications of CFP to Concrete Girder

Property	Test Method	Unit	Specifications
Carbon fiber plate weight	JIS R 7603	g/m^2	1200
Tensile Strength	JIS K 7073/ASTM D3039	N/mm^2	≥ 2400
Bond Strength to Concrete	JIS K5400/ASTM D7234	N/mm^2	≥ 1.5 CF

The material test shall be applied tensile strength test for CFP to be approved by the Engineer. CF – Concrete Failure

The epoxy adhesive for bonding CFS shall conform to the specifications shown in Table 5-13 or equivalent ASTM Specifications.

Table 5-13 Specifications of Epoxy Adhesive for Bonding CFS

Property	Test Method	Unit	Primer	Epoxy Putty	Penetrating Epoxy Resin
Viscosity	JIS K 6833/ ASTM D2393	mPa-s	≤ 1000	Paste-like	15,000±5000
Tensile Strength	JIS K 7113/ ASTM D638M	N/mm^2	≥ 15	-	≥ 30
Flexural Strength	JIS K 7203/ ASTM D790M	N/mm^2	≥ 20	≥ 15	≥ 40
Compressive Strength	JIS K 7208/ ASTM D695M	N/mm^2	≥ 20	≥ 40	≥ 50
Modulus of Elasticity	JIS K 7208/ ASTM D695M	N/mm^2	≥ 1500	≥ 1500	≥ 1500
Slant Shear Bond to Concrete	ASTM C882	N/mm^2	≥ 15	≥ 15	≥ 15
Adhesive Strength (Dry/Wet)	JIS K5400/ ASTM D7234	N/mm^2	≥ 1.5	≥ 1.5	≥ 1.5

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

The epoxy adhesive for bonding CFP shall conform with the specifications shown in Table 5-14 or equivalent ASTM Specifications.

Table 5-14 Specifications of Epoxy Adhesive for Bonding CFP

Property	Test Method	Unit	Specification
Specific Gravity	JIS K7112/ASTM D792	−	1.7±0.20
Flexural Strength	JIS K7203/ASTM D790M	N/mm^2	≥ 40
Compressive Strength	JIS K7208/ASTM D695M	N/mm^2	≥ 70
Modulus of Elasticity	JIS K7208/ASTM D695M	N/mm^2	≥ 4000
Tensile Strength	JIS K 7113/ASTM D638M	N/mm^2	≥ 25
Tensile Shear Bond	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Bond Strength to CFP & Concrete	JIS K5400/ ASTM D7234	N/mm^2	≥ 3.5

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

5-5-5-2 Construction Requirement

(1) Surface Preparation

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

(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) Prime Coat

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) Putty Application

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

- 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

For CFS

Prior to undercoating epoxy resin adhesive, ambient temperature at the work site shall be checked to confirm the curing conditions before applying the resin. 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 with ambient temperature and manufacturer's recommendation in 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

For CFP

The Contractor shall submit for the Engineer's 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 with ambient temperature and manufacturer's recommendation in 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^2

(6) Carbon Fiber Application (First Layer)

For CFS

The standard length of carbon sheet will be cut from 4 to 6 m. If standard cut length is exceeded, wrinkles will appear and installation becomes more difficult. The CFS shall be applied in accordance with the following procedures:

- Install the CFS in the longitudinal direction 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.

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

For CFP

CFP shall be cut to 4 to 6 m length and applied 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^2
- The adhesive layer shall be applied to the plates in a curved profile measuring 3 mm in the center 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) Over Coating Resin Application

For 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^2 is for reference purposes only. The actual quantity should be determined considering the ambient temperature and manufacturer's recommendation in the work site, subject to Engineer's approval.

For CFP

No over coating is required for CFP since no second layer is usually required.

(8) Carbon Fiber Sheet/Plate Application (Second Layer)

Repeat the steps for the first layer CFS application, except that the sheet will be placed in the opposite (transverse) direction.

(9) Quality Control and Inspection

The Contractor shall conduct a quality control program that includes, but 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 is carried out prior to CFS and CFP application.
- Inspection of work in progress to ensure work is being done in accordance with the DPWH Standard Specifications and approved manufacturer's instructions.
- Inspection of all work completed including sounding of all repairs to check for any debonding and correction of any defective work.

(10) Testing

After allowing at least 24 hours for the 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 the manufacturer's recommendations. The Contractor shall conduct adhesion testing of the fully cured CFS and CFP installation using direct pull-off tests, at locations determined by the Engineer. Failure at the bond line at tensile stress below 14 kgf/cm^2 (200 psi) will be the cause for rejection of the repair. 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 topcoat on the CFS or CFP.

5-5-6 Measurement and Payment

5-5-6-1 Method of Measurement

CFS installed in accordance with the plans and specifications will be measured in square meters, while CFP in liner meters. The quantity to be paid for will be the square meters of CFS or liner meters of CFP used and accepted by the Engineer. No measurement will be made for epoxy injection of cracks.

5-5-6-2 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 of the concrete as detailed in the plans and specifications. If an alternative carbon fiber system is used, the price shall also include all engineering, design, and technical services, as well as contractor submittals required as per specifications.

5-6 STEEL PLATE BONDING TO CONCRETE

5-6-1 Description of Repair Method

Steel plate is bonded with epoxy resin at the bottom or side face of existing girders. Bonded steel plate provides the same effect as that for installing additional rebar to existing girder.

This method is adopted for strengthening the slab or girder against bending moment as well as shear. Due to ease of application, this method as shown in **Error! Reference source not found.** is widely used. This measure is often performed for girders since it does not require restriction to traffic. However, in case where the deterioration of the concrete surface is too severe, other measures to improve the quality may be considered.

Figure 5-11 Repair of Concrete Girder by Steel Plate Bonding

5-6-2 Application Criteria

Steel plate bonding involves use of narrow steel plates installed in the longitudinal direction of the concrete girder. The bonding of steel plates to concrete members is achieved using pressure attachment method as discussed below.

Pressure Attachment Method

This method requires single plates of required thickness with gaps sealed at the edges between the steel and the concrete. Epoxy resin is injected to ensure that no voids occur between the plate and the concrete.

Pressure attaching method is normally adopted for narrow plate type considering the extent of surface preparation of both concrete and steel plate as shown in **Error! Reference source not found.**.

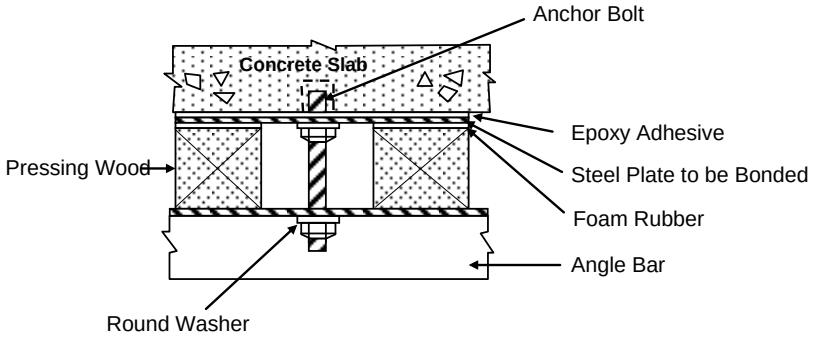


Figure 5-12 Detail of Pressure Attachment Method by Anchor Bolts

5-6-3 Work Sequence

(1) Surface Preparation

Bottom surface of concrete girder to be bonded with steel plate shall be cleaned. Any surface irregularities shall be leveled using a disc grinder.

The surface of the steel to be bonded must be completely free of any mill scale, rust,

grease or other contaminants. The primer should be applied on the surface which is compatible with the adhesive.

(2) Application of Epoxy Resin

The adhesive shall be thicker along the center of the steel plate than at its sides. The use of plastic spacers maintains minimum adhesive thickness of 1- 2 mm.

(3) Pressure Attachment of Steel Plate

The epoxy resin adhesive is applied to the steel plate which is set at the required position of the girder, and pressed using the anchor bolts wedging off with the temporary stiff wood and steel angle bar.

(4) Curing and Painting

A suitable chamfer/fillet could also be formed in the adhesive around the edge of the plates and the concrete surfaces. Steel plates and all its components shall be adequately painted for corrosion protection.

5-6-4 Required Materials and Tools/Equipment

5-6-4-1 Required Materials

- Steel Plate
- Primer (Epoxy Base)
- Epoxy Resin Adhesive
- Epoxy Sealant
- Anchor Bolts
- Wood and Angle for Fitting

5-6-4-2 Required Equipment/Tools

- Disc Grinder

- Welder
- Electric Drill
- Epoxy Injection Pump with Accessories
- Wire Brush

5-6-5 Specification

5-6-5-1 Material Requirement

The epoxy resin adhesive shall conform to the specifications shown in **Error! Reference source not found.** or equivalent ASTM Specifications.

Table 5-15 Specifications of Epoxy Resin Adhesive for Steel Bonding to Concrete

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.16±0.1
Flexural Strength	JIS K k 7203/ASTM D790M	N/mm^2	≥ 40
Compressive strength	JIS K 7208/ASTM D695M	N/mm^2	≥ 70
Tensile Strength	JIS K 7113/ASTM D638	N/mm^2	≥ 40
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 15
Bond Strength to Concrete Dry / Wet	JIS K5400 / ASTM D7234	N/mm^2	≥ 3.5

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

5-6-5-2 Construction Requirement

(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 allow loss of adhesive 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 fabricators premises. The primer, for the epoxy resin adhesive, should be an epoxy based system which is compatible with the adhesive.

(2) Steel Plate Setting

Steel plate shall comply with JIS or Equivalent Standard. The use of high yield steel does not exceed 150 N/mm^2 which is equivalent to SS400 class for JIS Standard. Minimum plate thickness should not be less than 4mm in order to avoid distortions during grit blasting and handling on site. Anchor bolts required to temporarily support steel plates in the event of setting on the girder. The bolt spacing should be sufficient to prevent deflection of the bonded plate within the defined headroom. Concrete structures to which plates are to be bonded shall be invariably smoothened and surface burnished using a disc grinder.

(3) Application of Epoxy Resin

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. Epoxy resin adhesive shall be spread immediately after mixing to dissipate the heat generated and extend its workability time. The adhesive shall be spread thicker along the center of the steel plate than

at its sides. The use of plastic spacers maintains the minimum adhesive thickness of 1-2 mm. Excess adhesive can then be scraped.

(4) Pressure Attachment of Steel Plate

The epoxy resin adhesive is applied to the steel plate which is set at the required position of the girder, and pressed using the anchor bolts wedging off with the temporary stiff wood and steel angle bar, in accordance with the shop drawings approved by the Engineer.

(5) 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 could also be formed in the adhesive around the edge of the plates and the concrete surfaces. Steel plates and all associated components shall be adequately painted for corrosion protection.

5-6-6 Measurement and Payment

5-6-6-1 Basis of Measurement

Steel plate bonding performed in accordance with the plans and this specification will be measured in square meters. The quantity to be paid for will be the square meters of steel plate bonded on the girder and accepted by the Engineer. No measurement will be made for epoxy injection of cracks, if required.

5-6-6-2 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 of the girder with steel plate as detailed in the plans and specifications.

5-7 PROTECTIVE MORTAR

5-7-1 Description of Repair Method

If the bridge is located less than 1km from coastal area, concrete member will be deteriorated due to salt attack. As explained in Section 3-2-2, it is recommended to apply protective mortar as preventive maintenance.

Protective mortar is made from polymer cement with lithium nitrate which is effective against chloride ions.

After or during application of appropriate repair method, protective mortar shall be applied to concrete member.

Photo 5-3 Protective Mortar applied on Girder Surface

Photo 5-4 Protective Mortar applied on Patching Surface

5-7-2 Application Criteria

In application of repair method like patching, recasting and so on for deteriorated concrete member, location of bridge shall be considered. If the bridge is located less than one (1) km from coastal area, deterioration of concrete member by salt attack always occur. If defect of delamination and/or spalling is found, it is sign of salt attack.

There are two (2) thicknesses used in applying protective mortar. Apply 6mm thickness of protective mortar to surface of concrete member with severely deteriorated areas and/or repaired area. Apply 1mm thickness of protective mortar to surface of concrete member for preventive maintenance.

5-7-3 Work Sequence

(1) Surface Preparation

Entire surface of coating area should be cleaned by using cup wire brush and/or disc sander.

(2) Keep Dry Condition and Avoid Sunshine

Always stockpile PCM with Lithium Nitrite powder in dry place and avoid sunshine or direct sunlight.

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(3) Weigh PCM with Lithium Nitrite

PCM with Lithium Nitrite consists of Lithium Nitrite and premix type non-shrink mortar. Measure one (1) kg of powder by digital weigh scale with less than one (1) gram margin of error.

(4) Weigh the Emulsion

Emulsion consist of Lithium Nitrite and adhesive. Measurements shall be kept accurate by using digital weigh scale with less than one (1) gram margin of error.

(5) Mix Powder and Emulsion

One (1) kg of powder and 180g of emulsion shall be mixed by hand. Use rubber gloves. During mixing, do not water.

(6) Application of PCM with Lithium Nitrite

Apply and spread PCM with Lithium nitrite on surface to be patched using trowel and/or brush.

(7) Curing of PCM with Lithium Nitrite

Spray water on patched surface for 3days continously.

5-7-4 Required Materials and Tools/Equipment

5-7-4-1 Required Materials

- Polymer cement mortar with lithium nitrite
- Emulsion made of lithium nitrite and adhesive

5-7-4-2 Required Equipment/Tools

- Power disk grinder/cutter
- Portable generator
- Trowel
- Brush/Roller

5-7-5 Specification

5-7-5-1 Material Requirement

Protective mortar by PCM with Lithium Nitrite shall conform to the requirements of the Specification as shown in Table 5-16 or equivalent ASTM Specification.

Table 5-16 Specifications of PCM with Lithium Nitrite

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM C-39 or JHS416	N/mm2	28 days ≥ to33
Bonding strength to concrete	JHS416	N/mm2	2.0 (wet condition)
Bleeding Rate	ASTM C940 or JHS416	%	0.04
Consistency	JHS416	Sec	6~10
Finishing appearance			Homogeneous appearance
Workability			No hanging, shearing, peeling-off and bulging

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

5-7-5-2 Construction Requirement

(1) Surface Preparation of Concrete

If an area of concrete member will be patched with PCM with Lithium Nitrite, deteriorated concrete shall be chipped off by using drill and hammer.

(2) Material Handling

Material of protective mortar shall be kept in good condition (dry and away from sunlight). When powder and emulsion are mixed, never add water to the mixture.

(3) Application of Protective Mortar

Protective mortar of 1mm thickness shall be applied on surface of concrete except at areas requiring 6mm thickness. Protective mortar of 6mm thickness shall be applied on the surface if deterioration is in severe condition. Also, if it is necessary to chip-off defective portion on the concrete member, protective mortar of 6mm thickness shall be applied to the surface prior to repair of defective portion.

(4) Quality Control and Inspection

The contractor shall conduct a quality control program that includes, but 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 protective mortar application.
- Inspection of all work in progress to ensure work is being done is in accordance with DPWH Standard Specifications, and approved manufacturer's instructions.
- Inspection of all work completed including verification of all repairs for objective surface.

5-7-6 Measurement and Payment

5-7-6-1 Basis of Measurement

The method of measurement to determine payment for protective mortar shall be based on the total applied area, as identified by the Engineer.

5-7-6-2 Basis of Payment

The contract price paid per square 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 of surface cleaning, completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

5-8 PROTECTIVE COATING

5-8-1 Description of Repair Method

If the bridge is located more than 1km from coastal area, concrete member will be deteriorated due to carbonation. As discussed in Section 3-2-2, it is recommended that protective coating should be applied as preventive maintenance.

Protective coating is made from acryl urethane based coating which is effective against Carbon dioxide, weather/UV rays, chemical and oil damage.

After repairing damage, protective coating shall be applied on the concrete member.

Photo 5-5 Protective Coating applied on Surface of Superstructure

5-8-2 Application Criteria

Protective coating shall be applied to surface of concrete member for preventive maintenance.

Material is an acryl urethane based coating characterized by weather / UV resistance, chemical and oil resistance needed for the protection of concrete and steel structures. The Base Resin and Hardener are mixed at a ratio by weight of 4: 1, respectively. Coating is normally applied for 1 to 3 coats.

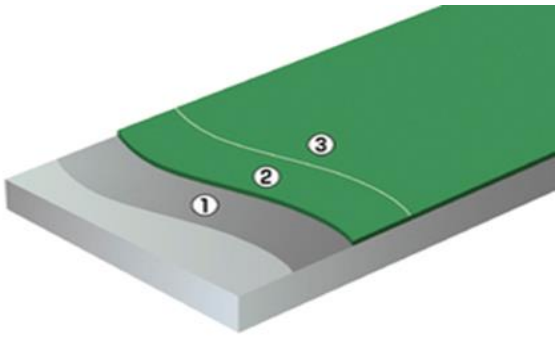
5-8-3 Work Sequence

(1) Surface Preparation

Entire surface of coating area should be cleaned by using cup wire brush and/or disc sander

(2) Mixing Acryl Urethane Protective Coating Materials

Acryl urethane based coating is characterized by its resistance to weather/UV, chemicals and oil necessary for the protection of steel and concrete structures. The Base Resin and Hardener are mixed at a ratio by weight of 4: 1, respectively.



(3) Application of Protective Coating

Acryl Urethane Protective Coating is applied by roller and/or brush on surface to be coated. Interval time between application of first layer and second layer is minimum 3 hours for next coating. Coating is normally applied for 1 to 3 coats.

5-8-4 Required Materials and Tools/Equipment

5-8-4-1 Required Material

- Base Resin 16 Kg (Tin Can)
- Hardener 4 Kg (Tin Can)

5-8-4-2 Required Equipment/Tools

- Power Disc Grinder/Cutter
- Portable Generator
- Paint Roller and Paint Brush

5-8-5 Specification

5-8-5-1 Material Requirement

Acryl Urethane Protective Coatingshall conform to the requirements of the Specification as shown in Table 5-17 or equivalent ASTM Specification.

Table 5-17 Specification of Protective Coating

Property	Test Method	Unit	Specifications
Bond Strength	ASTM D3359 or ASTM D7234	N/mm2	≧1.5
Tap Water Resistance	ASTM D6943	-	No Change
Acid Resistance(5%H_2SO_4)	ASTM D6943	-	No Change
Alkali Resistance(5%NaOH)	ASTM D6943	-	No Change

The material shall undergo quality tests and confirm to the above specifications

5-8-5-2 Construction Requirement

(1) Surface Preparation of Concrete

Surface preparation shall be conducted by using electric disc grinder and/or brush.

(2) Material Handling

After mixing base resin and hardener, protective coating shall be applied to the surface within hardening period of about 3 hours.

(3) Application of Protective Coating

Apply 1 to 3 coats, normally.

(4) Quality Control and Inspection

The contractor shall conduct a quality control program that includes, but 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 protective coating application.
- Inspection of all work in progress to ensure work is being done is in accordance with DPWH Standard Specifications, and approved manufacturer's instructions.
- Inspection of all work completed including verification of all repairs to the surface.

5-8-6 Measurement and Payment

5-8-6-1 Basis of Measurement

The method of measurement to determine payment for protective coating shall be based on the total applied area, as identified by the Engineer.

5-8-6-2 Basis of Payment

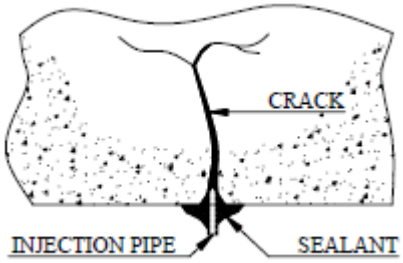
The quantity, measured as prescribed above, shall be paid for at a contract unit price. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related necessary works for protective coating.

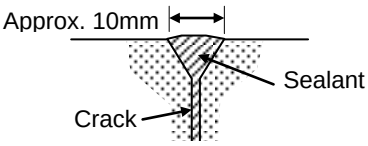
CHAPTER 6 REPAIR OF CONCRETE BRIDGE SUBSTRUCTURE

6-1 CAULKING

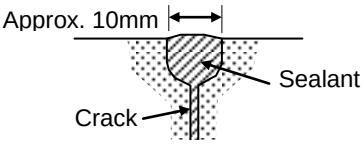
6-1-1 Description of Repair Method

Active cracks are treated and repaired with flexible sealants as shown in Figure 6-1. 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.





(V-Type)



(U-Type)

Figure 6-1 Types of Caulking

6-1-2 Application Criteria

Crack widths could be more than 3.0 mm with depth of less than 300 mm. In this case, the top surface edges should be chipped or sawn to form a V-type or U-type groove, in order to provide a caulking for inlet of gravity flow of resin into the crack by injection pump.

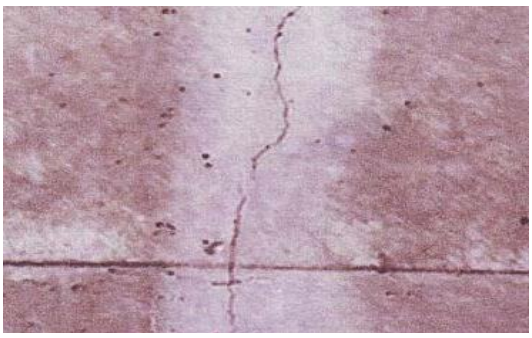
Cracks wider than 3.0 mm generally require epoxy based injection material (mix of epoxy and mineral filler).

Active cracks are treated and repaired with flexible sealants. 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. The crack movement should be calculated taking into account the applied loads, shrinkage and temperature variations.

6-1-3 Work Sequence

(1) Clean the cracks.

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. Remove the residual water or solvent in the crack with filtered (dust and oil free) compressed air and allow adequate time for drying.



(2) Preparation of Caulking

Using a concrete saw, hand tools or pneumatic tools, a V-groove or U-groove, approximately 10 mm in width and in depth, is prepared at the surface along the crack. The groove shall then be partially sealed with a sealant.

(3) Drilling Holes and Fixing Injection Pipes

Port holes are drilled near the crack, or in the groove. Injection pipes are then fixed at the tip of the groove. Spacing between ports varies between 150 mm to 500 mm, generally depending on the width and depth of the cracks.

The groove is then completely sealed with sealant.

(4) Injecting the Epoxy Grout

Epoxy grout can be injected using injection pumps, or air-activated caulking guns. Duration of injection process shall be in accordance with the supplier instructions.

For horizontal cracks, the injection is carried out from the injection pipe at end of the crack to the other end.

(5) Curing of Injected Material

After the crack is sealed, the projecting injection pipes are cut and the holes are filled with epoxy patching compound. If surface coating or carbon fiber sheet will be applied, the portions with sealant and tip of cut pipe should be grinded to form a smooth surface.

6-1-4 Required Materials and Tools/Equipment

6-1-4-1 Required Materials

- Epoxy Grout
- Sealant

6-1-4-2 Required Equipment and Tools

- Epoxy Injection Pump
- Power Disc Grinder
- Portable Generator
- Brush
- Concrete Saw
- Electric Drill

6-1-5 Specifications

6-1-5-1 Material Requirement

(1) Epoxy Grout

The epoxy grout material shall be compatible with the host concrete and shall have the properties listed in below Table 6-1. Testing of materials shall be in accordance with the relevant standards shown or equivalent ASTM Specifications.

Table 6-1 Specification of Epoxy Based Injection Material for Substructure

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.1 ± 0.1
Viscosity	JIS K 6833/ ASTM D2393	mPa-s	≤ 2000
Consistency	-	-	Liquid
Pot Life	-	minutes	≥ 30
Elongation	JIS K 7113/ASTM D638M	%	50
Bond Strength Dry Concrete Wet Concrete	JIS K6852/ASTM C882	 N/mm^2 N/mm^2	 3.0 3.0

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

(2) Sealant

The epoxy based sealant material shall be compatible with the injection material and shall have the properties listed in Table 6-2. Testing of materials shall be in accordance with the relevant standards as shown or equivalent ASTM Specifications.

Table 6-2 Specification of Epoxy Based Sealant to Substructure

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.5 ± 0.3
Consistency	-	-	Paste-like
Pot Life	-	minute	≥ 30
Elongation	JIS K 7113/ASTM D638M	%	50
Bond Strength Dry Concrete Wet Concrete	JIS K6852/ASTM C882	 N/mm^2 N/mm^2	 3.0 3.0

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

6-1-5-2 Construction Requirement

(1) Preparation of Concrete

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, as stated in the Bridge Inspection Manual of BMS. 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.

At loose or spalled areas of concrete, grease, oil or other contaminants shall be removed. If necessary, wire brushes, grinding wheels or power brush shall be used as cleaning devices. Loose or spalled areas of concrete, laitance, traces of paint or other coating materials within the marked out scope of work shall be removed.

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 for Caulking

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 4.2.1, at the surface along the crack. Clean the groove with an oil free air jet or wire brush and allow drying completely before placing the sealant. The sealant shall be applied in accordance with the manufacturer's instructions.

(3) Drilling Holes and Fixing of Injection Pipes

The injection pipes shall be fixed at intervals along the direction of each crack. The distance between each pipe shall be shown on drawings considering the width and the depth of crack, for approval of the Engineer. The 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 marker. Mixing is continued until a uniform paste is obtained.

Holes for injection pipes are drilled near the crack or in the groove until the tip of holes reach the full depth of crack. The injection pipes are inserted into the holes and fixed with epoxy adhesive. The mixed sealant shall be applied into the groove along the cracks as a caulking. 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.

(4) Grout Injection

Each crack shall be treated in a single, continuous operation. Sufficient grout material shall therefore be readily available prior to the commencement of the works.

The grout 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 Contactor shall propose suitable grout material based on the study on the crack movement, subject to Engineer’s approval.

The preparation, mixing and application of the grout materials shall be strictly undertaken in accordance with the manufacturer’s recommendations. The Contractor shall ensure that all necessary tools and equipment are on site before the works commence.

The injection resin shall be of a pre-packed type and only the use of full units will be allowed. No part packs or on-site batching will be allowed under any circumstances. In all operations of storage, mixing and application, the Contractor is to comply with the Health and Safety recommendations of the Engineer and the relevant governing authorities.

(5) Curing

The grout shall be allowed to cure for twenty-four (24) hours and shall be left undisturbed during the entire time. The injection pipes are cut after confirmation of hardening. The tip of injection pipe shall be cut and bands of surface sealant of caulking shall be smoothened for the succeeding works.

(6) Performance Test

Low Frequency Pulse Velocity Ultrasonic Inspection shall be conducted to determine if the epoxy resin has penetrated the root of the crack. If incomplete penetration is revealed by inspection, the Contractor shall redo the work at his own expense.

6-1-6 Measurement and Payment

6-1-6-1 Method of Measurement

The method of measurement to determine the payment for the caulking shall be based on the total length of the cracks, to be determined by the Engineer.

6-1-6-2 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.

6-2 PATCHING

6-2-1 Description of Repair Method

Patch repair 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. The patch thickness is limited to a maximum of 100 mm depth of hollow surface.

Type A Patching is used for defects without exposed rebar while Type B Patching is applied to defect of surfaces with exposed rebar.

Patch repairs may be composed of Portland cement mortars or non-shrinkage cement mortar, depending on the type of patching, location and extent of damage.

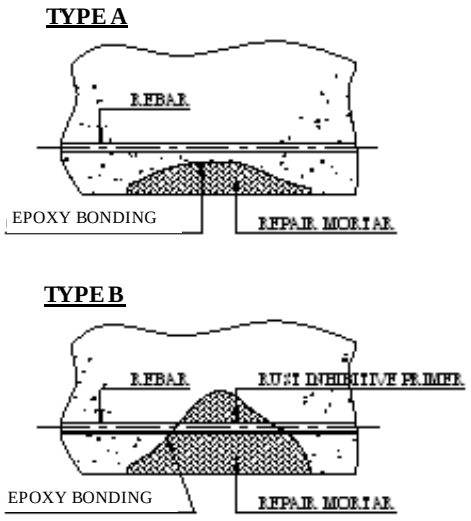


Figure 6-2 Types of Patching

6-2-2 Application Criteria

Patch repair is classified into two types as shown in Figure 6-2, considering defective area and surface. Type-A is applicable to surfaces without exposed rebar, having defective widths of up to 300mm and depths of up to 50 mm. Meanwhile, Type-B is used for surfaces with exposed rebar, with defective widths between 300 mm and 600 mm, and up to 100 mm depths.

Portland cement mortar is used for Type-A and Polymer cement mortar is used for Type-B.

6-2-3 Work Sequence

(1) Removal of Defective Concrete

Remove all defective, unsound and contaminated concrete and prepare the edges for the patch area. If local corrosion in reinforcement with section loss is found, which would require additional bars, remove only the damaged area of concrete including the length needed to bond the new reinforcement as shown in Figure 6-3.

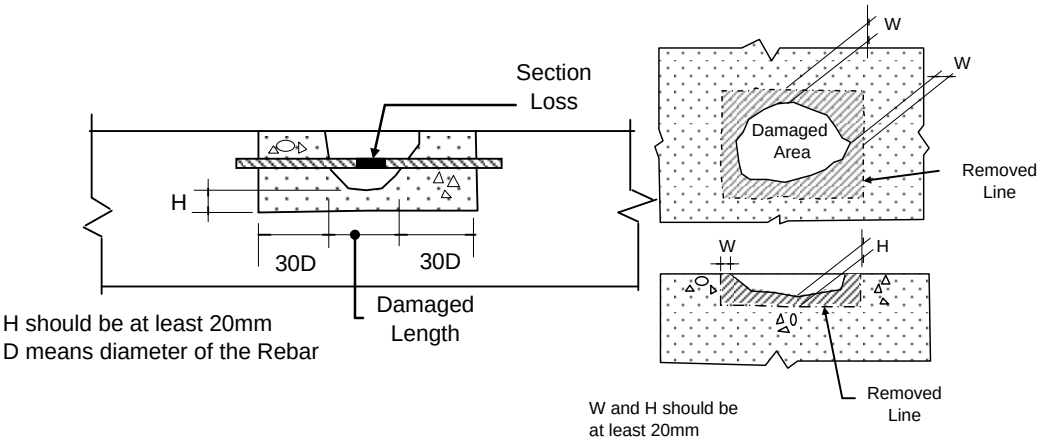


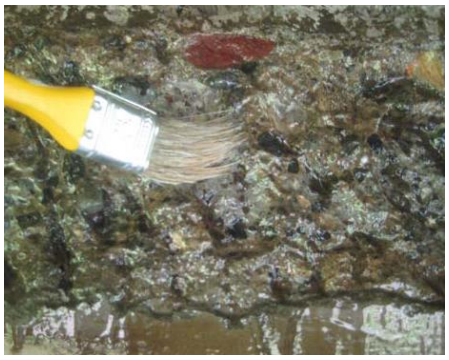
Figure 6-3 Removal of Damaged Concrete

(2) Chipping and Cleaning of Concrete Surface

Concrete within marked out areas shall be removed using light mechanical breakers or hammer and chisel to expose the reinforcement and a sound concrete substrate. The substrate shall be cleaned by brush to remove concrete dust.

(3) Application of Epoxy Bonding Resin

The concrete substrate area is coated with epoxy bonding resin in order to ensure adherence to patching and reinforce the repair. If rebar is exposed, anti-corrosion coating is applied to the bar surface.



(4) Placing Cement Mortar

Prepare the mortar mix in a bucket. Use a trowel to spread fresh mortar over the area, covering any nails driven halfway into the old concrete (if nails/bids are provided to further reinforce the repair). Smoothen and level the mortar using the trowel.

It should be noted that polymer cement mortar is suitable for both vertical or horizontal surface applications, with a thin coating of up to 15 mm. As may be required, it can be smoothened using a trowel or broom finished.

(5) Curing

All types of concrete repair need thorough and continuous curing to develop strength and impermeability. Curing also minimizes drying shrinkage while bond strength is developing.

6-2-4 Required Materials and Tools/Equipment

6-2-4-1 Required Materials

Portland Cement Mortar	**Polymer Cement Mortar (PCM)**
- Portland Cement	- PCM Powder
- Sand	- PCM Emulsion
- Water	- Concrete Nail
- Concrete Nail	- Bonding Agent to Concrete (Epoxy Bonding)
- Bonding Agent to Concrete (Epoxy Bonding)	

6-2-4-2 Required Equipment

- Chisel
- Portable Generator
- Wire Brush
- Small Hammer
- Mortar Mix Bucket
- Safety goggles
- Trowel
- Dust mask

6-2-5 Specifications

6-2-5-1 Material Requirement

Portland Cement Mortar shall conform to the requirements of Item 405, Structural Concrete, DPWH Standard Specifications. Strength test for Portland cement mortar shall be based on ASTM C 780

The polymer cement mortar shall conform with the specifications shown in Table 6-3 or equivalent ASTM Specification.

Table 6-3 Specifications of Polymer Cement-Based Patching Material

Property	Test Method	Unit	Specification
Compressive Strength	JSH 416/ASTM C39	N/mm2	At 28 days: ≥ 25
Bonding Strength to Concrete	JHS 416/ASTM D 7234	N/mm2	≥ 1.5
Bleeding Rate	JHS 416/ASTM C 39	%	0

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

The epoxy bonding primer to be applied to concrete shall conform to the specifications shown in Table 6-4 or equivalent ASTM Specification.

Table 6-4 Specifications of Bonding Primer to Concrete for Patching

Property	Test Method	Unit	Specifications
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	75
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	40
Tensile Strength	JIS K 7113/ASTM D638M	N/mm^2	30
Tensile Shear Bond to Steel	JIS K 6850/ASTM D1002	N/mm^2	10
Slant Shear Bond to Mortar	JIS K6852/ASTM C882	N/mm^2	15

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

The zinc-rich primer to be applied to rebar shall be in accordance with the specifications shown in Table 6-5.

Table 6-5 Specification of Zinc Rich Primer to Rebar for Patching

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

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

6-2-5-2 Construction Requirement

(1) Removal of Damaged Concrete

Damaged concrete within the marked out areas shall be removed using light mechanical breakers or hammer and chisel, cutting to expose the reinforcement and a sound concrete substrate to the satisfaction of the Engineer, without breaking out behind the reinforcement.

(2) Concrete Surface Preparation

All concrete surfaces that are to receive repair mortar shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss, and then coated by bonding primer. Care shall be taken to ensure that vibration from the method of preparation does not cause delamination of adjacent material or concrete.

(3) Additional Concrete Breakout

Where the breakout indicates that the exposed reinforcement is further corroded or the surrounding concrete is not sound, the Contractor shall be informed and an enlarged area is agreed to the satisfaction of the Engineer.

The Contractor shall test the concrete for depth 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 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, care shall be taken to minimize damage to existing

reinforcement.

(4) Additional or Replacement Rebar

The Contractor shall report to the Engineer any rebar which that has 10% or more section loss as a result of corrosion. Additional or replacement rebar shall be provided as instructed by the Engineer. The new rebar shall be cleaned to the same standard as the existing rebar and shall be lapped on the side of the existing bars and 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 then applied with zinc-rich primer to prevent further corrosion. The Contractor shall obtain Engineer's approval for the rebar prior to proceeding with repair mortar application.

(5) Method of Mortar Placing

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. 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. 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.

(6) Curing

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.

6-2-6 Measurement and Payment

6-2-6-1 Method of Measurement

The Engineer shall measure the area prepared for patching 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 satisfactorily completed.

6-2-6-2 Basis of Payment

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

6-3 RECASTING CONCRETE/GROUT

6-3-1 Description of Repair Method

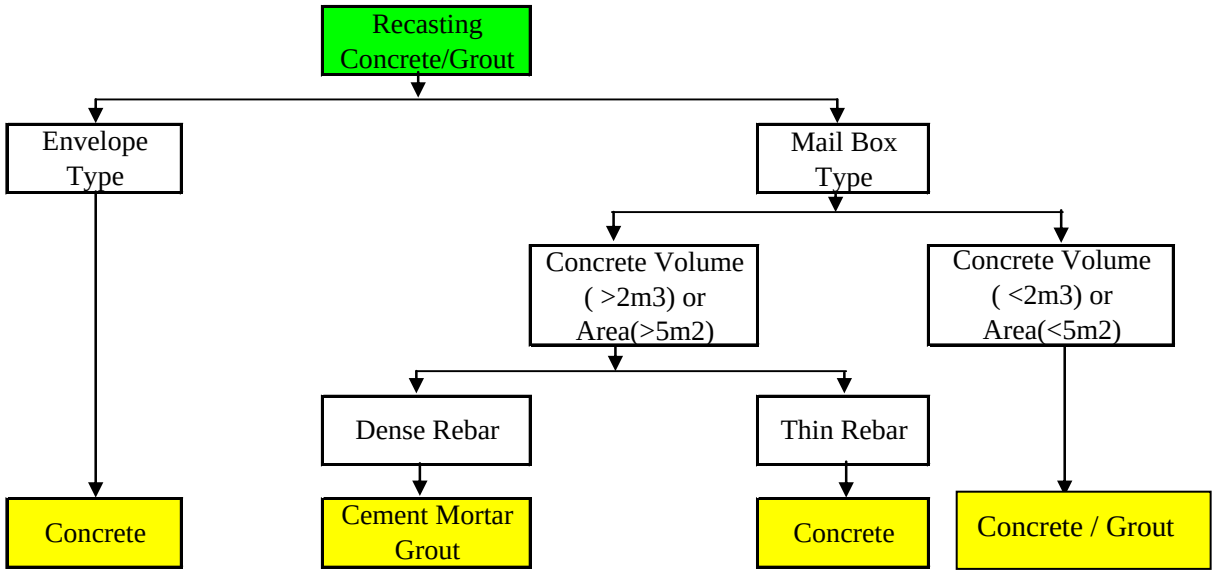
Recasting Method, which involves casting of the damaged area, by placing concrete or grouting mortar on the formwork, is usually most suitable for severely damaged concrete, or for largely damaged areas with densely spaced rebars as shown in Figure 6-1. If concrete placing by vibration is often a problem, grout and free flowing self-compacting concrete should be developed to minimize the vibration required.

Photo 6-1 Damaged Pier for Repair by Recasting

6-3-2 Application Criteria

Recasting Concrete/Grout is divided into two methods namely: concrete placing and mortar grouting types. The mortar grouting type shall be applied Portland cement grout.

Considering the position and scale of damage, applications of the recasting concrete and grout are classified according to the formwork types, such as the "Envelope Type" and "Mail Box Type," shown in Figure 6-4. Envelope type is open at the top for pouring concrete while the mail box type consist of holes or slit at its side for purposes of grouting or pumping mortar. Mail box type formwork is further classified based on concrete volume, applied area and rebar arrangement as also shown in Figure 6-4, with due consideration to cost performance.



Note: Both Formwork of Envelope Type and Mail Box Type is shown in Figure 5-8

Figure 6-4 Flowchart of Selection Method for Recasting Concrete

6-3-3 Work Sequence

The work sequence of concrete mixing, pouring and curing is in accordance with Section 4-6-3 and 4-6-5 of "PARTIAL DECK SLAB REPLACEMENT". The following work sequence is only for cement mortar grout and non-shrink grout.

(1) Removal of Damaged Deck Slab Concrete

All deteriorated or damaged concrete are cut using saw to form the vertical edges, and then removed using a breaker and chisel. Rebar are examined for loss of section due to corrosion. If cross sectional area of the reinforcement has reduced by more than 15%, provide extra reinforcements, as necessary.

(2) Preparation of Old Concrete and Rebar

A suitable bonding agent for concrete and reinforcement should be selected taking into consideration its limited working time available for fixing the formwork and placing the new concrete. Concrete should be placed immediately after applying bonding coat to the faces of old concrete and rebar.

(3) Cutting Existing Rebar and Adding New Rebar

Deteriorated old rebar are cut up to the required lap length. New bars to be provided shall be of same or bigger diameter than the existing, considering the current loading condition. The lap length is calculated as 30 times the new rebar diameter. The new rebar shall be tied to the existing bars using tie wires or by welding.

(4) Setting Formworks

Formwork for re-casting the girder must be very rigid and well-supported to prevent the new concrete from sagging due to its own weight.

(5) Mixing Mortar

Cement mortar grout shall be composed of one part cement, three parts sand, and a minimum amount of water necessary for the mixture to flow under its own weight, and then mixed using a grout mixer.

(6) Mortar Placing

The mortar has to be carefully placed to avoid the entrapment of air. Pumping is usually employed for the mail box type formwork which can be used for smaller pours. When pumping is used, the delivery hose should be at a low position while pouring, to allow the air to be displaced.

(7) Curing and Removal of Formworks

Continuous water curing by spraying 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.

6-3-4 Required Materials and Tools/Equipment

6-3-4-1 Required Materials

For Concrete

- Portland Cement
- Silica fume
- Aggregate/Sand
- Rebar (Reinforcing bar, Grade 60)
- Bonding Coat to Concrete (Epoxy Resin Adhesive)
- Anti-corrosion Primer to Rebar (Zinc Rich Primer)
- Cotton mat (Curing)

For Mortar

- Portland Cement (Cement Mortar)
- Admixture for consistency
- Reinforcing Bar
- Bonding Coat to Concrete (Epoxy Resin Adhesive)
- Anti-corrosion Primer to Rebar (Zinc Rich Primer)

6-3-4-2 Required Tools/Equipment

- 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

6-3-5 Specifications

6-3-5-1 Material Requirement

(1) Concrete Mixture

The mixture of concrete for recasting is guided below as reference. These quantities will make about 0.03 cubic meter of concrete and would be fully accommodated in a small mixer.

1) Cement
   - Portland cement 13.0 kg
   - Silica fume 0.5 kg (If silica fume is unavailable, use 13.5kg cement)

2) 10mm Crushed Aggregate 36.0 kg

3) Sand (assumed with 2% water content) 18.5 kg

4) Water (maximum) 5.4 liters

5) Super plasticizer (nominal) 25ml

The actual mix portion shall be determined during a field mixture test and approved by the Engineer.

The epoxy bonding primer to concrete shall conform to the specifications shown in Table 6-6 or equivalent ASTM Specification.

Table 6-6 Specifications of Bonding Primer to Concrete for Recasting

Property	Test Method	Unit	Specifications
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	75
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	40
Tensile Strength	JIS K 7113/ASTM D638M	N/mm^2	30
Tensile Shear Bond to Steel	JIS K 6850/ASTM D1002	N/mm^2	10
Slant Shear Bond to Mortar	JIS K6852/ASTM C882	N/mm^2	15

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

The zinc-rich primer to be applied to rebar shall be in accordance with the specifications shown in Table 6-7.

Table 6-7 Specifications of Zinc-Rich Primer to Rebar for Recasting

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

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

6-3-5-2 Construction Requirement

(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 deep around the perimeter to be replaced. Substructure concrete is removed by breaker and portable electric chisel near the vertical edges.

(2) Preparation of Concrete and Rebar surface

The concrete surface to which the bond coat is to be applied shall be wetted 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 substrate 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. Using a brush, the bond coat shall be applied to the exposed concrete surface and exposed reinforcement. The subsequent repair material shall be applied while the bond coat is still wet or tacky.

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.

(3) Adding Rebar

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

Tying of loose bars will be required. Rebar which have been cut or have lost 25 percent or more of their original cross sectional area shall be supplemented with new reinforcement bars. New bars shall be overlapped with a minimum of 30 bar diameters to existing bars. An approved mechanical bar splice capable of developing in tension at least 125 percent of the yield strength of the existing bar shall be used when it is not feasible to provide the minimum bar overlapping.

(4) Setting Formwork

The Contractor shall submit the shop drawings of the formwork of recasting concrete prior to the commencement of the repair works for the Engineer's approval. The formwork for re-casting 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 pumped 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 used should be compatible with the repair materials, particularly epoxy based and latex modified concrete and grouts.

(5) Mixing and Placing Mortar

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.

All large damaged areas shall be re-casted to accurately restore the original face of the substructure. 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 curing by spraying 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 and non-shrink 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.

6-3-6 Measurement and Payment

6-3-6-1 Basis of Measurement

Recasting concrete/grout performed in accordance with the plans and 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 substructure and accepted by the Engineer. The measurement made for rebar shall be in accordance with the DPWH Standard Specifications.

6-3-6-2 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 for as specified in the DPWH Standard Specifications. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related necessary works for supporting the substructure and scaffolding as detailed in the plans and specified herein.

6-4 JACKETING WITH CONCRETE

6-4-1 Description of Repair Method

Concrete jacket as shown in Figure 6-5 is mainly applied to substructure that has deteriorated concrete due to corrosion of rebar. It should be noted that splash zone portions of bridge concrete piles in marine environment are more exposed to corrosion. Although provision of jackets could delay further chlorides from entering the pile, this does not guarantee complete mitigation of corrosion to the rebars.

Steel jacketing remains an effective alternative for strengthening piers or piles against structural failure, however, it is not included in the scope of this manual

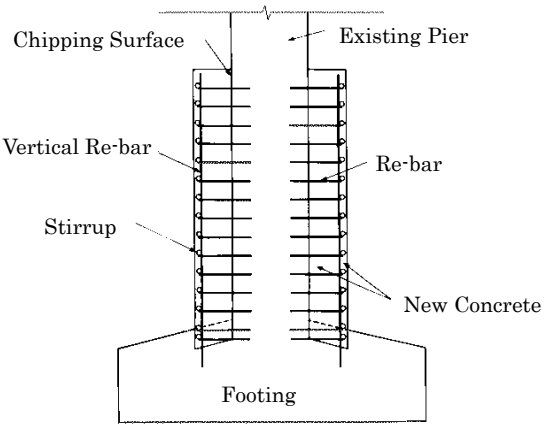


Figure 6-5 Concrete Jacketing

6-4-2 Application Criteria

Two methods of jacketing, namely concrete jacket and steel jacket, are discussed as follows:

Concrete jacket is applied to protect the deteriorated concrete due to corrosion of rebars, damage due to rapid water flow or broken due to continuous impact from materials flowing in the channel such as drift woods. Concrete jacket should be basically placed above water level as shown in Photo 6.2. If the damaged portion is submerged to water, cofferdam is necessary to achieve a dry condition during jacketing. To minimize cofferdam, related repair works are either carried out while water is at low level in the dry season, or using underwater concrete.

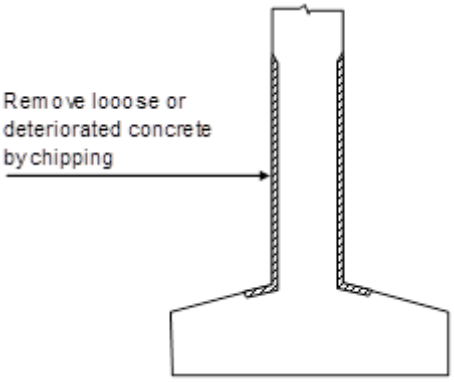
Photo 6-2 Concrete Jacket for Repair Pier

6-4-3 Work Sequence

(1) Removal of Deteriorated Concrete

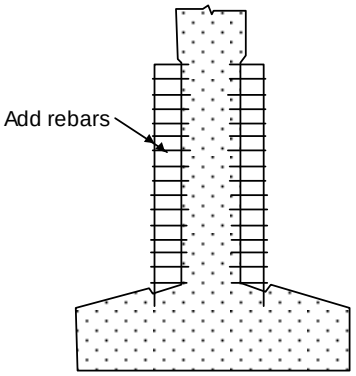
All loose or deteriorated concrete shall be removed. Surface cracks shall also be removed by chipping. Hammer sounding shall be done to locate delaminated areas.

When corroded reinforcing steel is exposed during concrete removal, the corroded bars shall be further exposed by chipping until clean un-corroded steel is exposed.



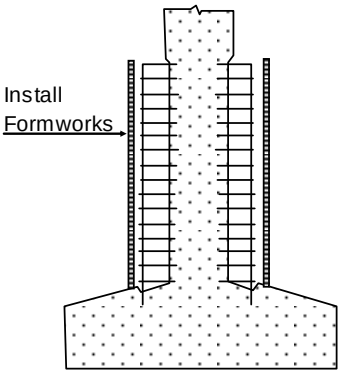
(2) Addition of Rebar

Additional rebar are anchored into drilled holes in the concrete, and placed in conformity with the requirements shown on drawings. Heavily corroded rebar shall also be replaced. Clear concrete cover to rebar, for piers and piles, shall be 40 mm in normal environment, and 55 mm in marine environment



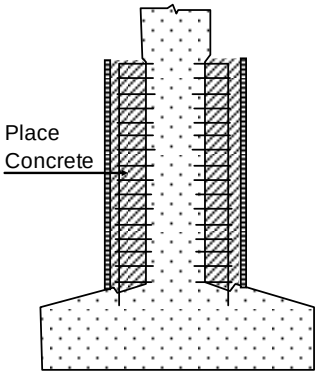
(3) Setting-up of Formworks

Formwork for concrete jacket is commonly circular or rectangular in shape. This formwork must be very rigid and well-supported to maintain the shape and the required covering of the new concrete. It should also be able to withstand pumping forces if concrete is to be pumped and vibrated.



(4) Placing of Concrete

Concrete is placed in the formworks through a suitable method and compacted well using internal or external vibrators. Surfaces shall be finished using broom, wood floating, and steel troweling to match the adjacent existing concrete.



(5) Curing of Concrete

Continuous water curing using wetted cotton mat is preferable to help slow down drying.

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.

6-4-4 Required Materials and Tools/Equipment

6-4-4-1 Required Materials

(1) Concrete with Fine Aggregate

A suggested 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 fully accommodated in a small mixer.

1) Cement

- Portland cement 13.0 kg
- Silica fume 0.5 kg (If silica fume unavailable, use 13.5kg cement)

2) 10mm Crushed Aggregate 36.0 kg

3) Sand (assumed with 2% water content) 18.5 kg

4) Water (maximum) 5.4 liters

5) Super plasticizer (nominal) 25ml

(2) Formwork

- Steel Formwork (Circular)
- Plywood formwork

6-4-4-2 Required Equipment/Tools

- Drilling Machine to Concrete
- Concrete Vibrator

6-4-5 Specifications

(1) Removal of Deteriorated Concrete

The Contractor shall remove all loose or deteriorated concrete as directed by the Engineer. Surface cracks shall be removed by chipping. Hammer sounding shall be done to locate delaminated areas. Care shall be taken not to damage areas of sound concrete, reinforcing steel or other bridge components. Any such damage will be repaired by qualified personnel at Contractor's expense.

Removal of deteriorated concrete from the bridge structure shall be done in such a manner that the structural integrity of the bridge is unaffected. All concrete removed shall be replaced as soon as possible. It is the responsibility of the Contractor to design and provide shoring, when required, as directed by the Engineer. The designed shoring shall be signed and sealed, and submitted to the Engineer for his approval.

(2) Additional Rebar

Additional rebar shall be firmly anchored into the drilled hole filled with epoxy resin adhesive and arranged in conformity with the requirements shown on drawings. Prior to drilling holes, location of existing rebar in the pier shall be verified using an ultrasonic recorder (rebar locator). Actual ideal location of drilled holes for the additional rebars shall be consequently marked.

When reinforcing steel appears corroded during concrete removal, further chipping shall be continued until clean and uncorroded portion of the bars are exposed. Chipping shall be done to a depth of 20 mm beneath the rebar. Perimeter of all chipped areas shall be saw cut to a minimum depth of 40 mm to minimize rough edges.

Rebar, which are exposed with significant section loss during repairs, shall be replaced as directed by the Engineer. In general this is implemented if the section loss at any portion of the rebar exceeds 20 percent. In cases of isolated section loss areas, the existing rebar need not be cut out, instead, extra rebar shall be added alongside in such a manner that voids will not occur during concrete placing. The minimum lap splice length of all new rebar required shall be 30 bar diameters. The minimum cover of new concrete above the reinforcing steel shall be 40 mm in normal environment and 55 mm in the marine environment.

(3) Setting-up of Formworks

The Contractor shall submit shop drawings, for the Engineer’s approval, of the formwork for the concrete jacket prior to commencement of the repair works. The formwork must be very rigid and well-supported to prevent the new concrete from leaking at the

bottom of the formwork. It should also be durable enough to withstand its own weight, pumping forces, (if concrete is to be pumped into the forms) and forces due to clamped-on external vibrators.

Circular formwork, when required, should be made up of steel plate or appropriate materials approved by the Engineer. The diameter of the formwork shall be fabricated 500 mm larger than the existing pier or pile diameter. This is necessary in order to provide a space of 250 mm between the formwork and the surface of existing concrete, which is required for placing new concrete and inserting poker vibrators.

(4) Placing of Concrete

Placing of concrete shall be in accordance with Item 405.4.4 of the DPWH Standard Specifications.

(5) Curing Concrete

Concrete curing shall be in accordance with Item 405.4.4 of DPWH Standard Specifications.

6-4-6 Measurement and Payment

6-4-6-1 Basis of Measurement

Concrete jacketing performed in accordance with the plans and this specification will be measured in cubic meters. The quantity to be paid for will be the cubic meters of concrete placed around the piers/piles and accepted by the Engineer. The measurement for rebar will be in accordance with the DPWH Standard Specifications.

6-4-6-2 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 for as specified in the DPWH Standard Specifications. This unit price shall include full compensation for all materials, labor, equipment, supervision, and related necessary works for supporting the substructure and scaffolding as detailed in the plans and specifications.

6-5 PROTECTIVE MORTAR

6-5-1 Description of Repair Method

If the bridge is located less than 1km from coastal area, concrete member will be deteriorated mainly by salt intrusion. As explained in Section 3-2-2, it is recommended to apply protective mortar as preventive maintenance.

Protective mortar is made from lithium nitrate polymer cement mortar which is effective against salt intrusion.

After or during application of appropriate repair method, protective mortar shall be applied to concrete member.

Photo 6-3 Protective Mortar applied on Substructure Surface

Photo 6-4 Protective Mortar applied on Patching Surface

6-5-2 Application Criteria

In application of repair method like patching, recasting and so on for deteriorated concrete member, location of bridge shall be considered. If the bridge is located less than one (1) km from coastal area, deterioration of concrete member by salt attack always occur. If defect of delamination and/or spalling is found, it is sign of salt attack.

There are two (2) thicknesses used in applying protective mortar. Apply 6mm thickness of protective mortar to surface of concrete member with severely deteriorated areas and/or repaired area. Apply 1mm thickness of protective mortar to surface of concrete member for preventive maintenance.

6-5-3 Work Sequence

(1) Surface Preparation

Entire surface of repair area should be cleaned by using cup wire brush and/or disc sander

(2) Keep Dry Condition and Avoid Sunshine

Always stockpile PCM with Lithium nitrite powder in dry place and avoid sunshine or direct sunlight.

(3) Weigh PCM with Lithium Nitrite

PCM with Lithium Nitrite consists of Lithium Nitrite and premix type non-shrink mortar. Measure one (1) kg of powder by digital weigh scale with less than one (1) gram margin of error.

(4) Weigh the Emulsion

Emulsion consist of Lithium Nitrite and Adhesive. Measurements shall be kept accurate by using digital weigh scale with less than one (1) gram margin of error.

(5) Mix Powder and Emulsion

One (1) kg of powder and 180g of emulsion shall be mixed by hand. Use rubber gloves. During mixing, do not add water.

(6) Application of PCM with Lithium Nitrite

Apply and spread PCM with Lithium Nitrite on surface to be patched using trowel and/or brush.

(7) Curing of PCM with Lithium Nitrite

Spray water on patched surface for 3days continously

6-5-4 Required Materials and Tools/Equipment

6-5-4-1 Required Materials

- Polymer cement mortar with lithium nitrite
- Emulsion made of lithium nitrite and adhesive

6-5-4-2 Required Equipment/Tools

- Power disk grinder/cutter
- Portable generator
- Trowel
- Brush/Roller

6-5-5 Specification

6-5-5-1 Material Requirement

Protective mortar made of PCM with Lithium Nitrite shall confirm to the requirements of the Specification as shown in Table 6-8 or equivalent ASTM Specification.

Table 6-8 Specifications of PCM with Lithium Nitrite

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM C-39 or JHS416	N/mm2	28 days ≥ to33
Bonding strength to concrete	JHS416	N/mm2	2.0 (wet condition)
Bleeding Rate	ASTM C940 or JHS416	%	0.04
Consistency	JHS416	Sec	6~10
Finishing appearance			Homogeneous appearance
Workability			No hanging, shearing, peeling-off and bulging

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

6-5-5-2 Construction Requirement

(1) Surface Preparation of Concrete

If an area of concrete member will be patched with PCM with Lithium Nitrite, deteriorated concrete shall be chipped off by using drill and hammer.

(2) Material Handling

Material of protective mortar shall be kept in good condition (dry and away from sunlight). When powder and emulsion are mixed, never add water to the mixture.

(3) Application of Protective Mortar

Protective mortar of 1mm thickness shall be applied on surface of concrete except at areas requiring 6mm thickness. Protective mortar of 6mm thickness shall be applied on the surface if deterioration is in severe condition. Also, if it is necessary to chip-off defective portion on the concrete member, protective mortar of 6mm thickness shall be applied to the surface prior to repair of defective portion.

(4) Quality Control and Inspection

The contractor shall conduct a quality control program that includes, but 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 protective mortar application.
- Inspection of all work in progress to ensure work is being done is in accordance with DPWH Standard Specifications, and approved manufacturer's instructions.
- Inspection of all work completed including verification of all repairs for objective surface.

6-5-6 Measurement and Payment

6-5-6-1 Basis of Measurement

The method of measurement to determine payment for protective mortar shall be based on the total applied area, as identified by the Engineer.

6-5-6-2 Basis of Payment

The contract price paid per square 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 of surface cleaning, completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

6-6 PROTECTIVE COATING

6-6-1 Description of Repair Method

If the bridge is located more than 1km from a coastal area, the deterioration of a concrete member will be mainly due to carbonation. As discussed in Section 3-2-2, it is recommended that protective coating should be applied as preventive maintenance.

Protective coating is made from acryl urethane based coating which is effective against carbonation, weather/UV rays, chemical and oil damage.

After repairing damage, protective coating shall be applied on the concrete member.

Photo 6.5 – Protective Coating applied on Substructure Surface

6-6-2 Application Criteria

Protective coating shall be applied to surface of concrete member for preventive maintenance.

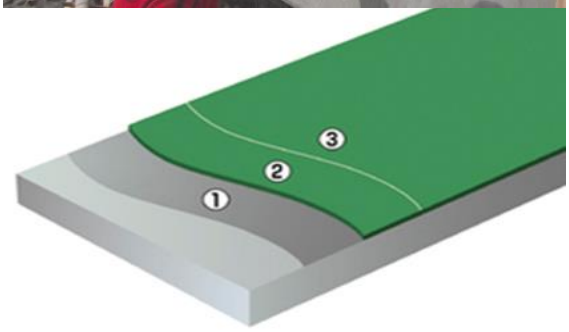
Protective Coating material is made of an acryl urethane characterized by weather / UV resistance, chemical and oil resistance needed for the protection of concrete and steel structures. The Base Resin and Hardener are mixed at a ratio by weight of 4: 1, respectively. Coating is normally applied for 1 to 3 coats.

6-6-3 Work Sequence

(1) Surface Preparation

Thoroughly clean surface to be coated by cup wire brush and disc sander.

(2) Mixing Acryl Urethane Protective Coating Materials



Acryl urethane based coating is characterized by its resistance to weather/UV, chemicals and oil necessary for the protection of steel and concrete structures. The Base Resin and Hardener are mixed at a ratio by weight of 4: 1, respectively.

(3) Application of Protective Coating

Application of Acryl Urethane Protective Coating is done by trowel and brush spread on objective surface. Interval time between application of first layer and second layer is minimum 3 hours for next painting. Coating is normally applied for 1 to 3 coats.

6-6-4 Required Materials and Tools/Equipment

6-6-4-1 Required Material

- Base Resin 16 Kg (Tin Can)
- Hardener 4 Kg (Tin Can)

6-6-4-2 Required Equipment/Tools

- Power Disc Grinder/Cutter
- Portable Generator
- Trowel
- Brush

6-6-5 Specification

6-6-5-1 Material Requirement

Acryl Urethane Protective Coating shall confirm to the requirements of the Specification as shown in Table 6.9 or equivalent ASTM Specification.

Table 6-9 Specification of Protective Coating

Property	Test Method	Unit	Specifications
Bond Strength	ASTM D3359 or ASTM D7234	N/mm2	≥1.5
Tap Water Resistance	ASTM D6943	-	No Change
Acid Resistance(5%H_2SO_4)	ASTM D6943	-	No Change
Alkali Resistance(5%NaOH)	ASTM D6943	-	No Change

The material shall undergo quality tests and confirm to the above specifications

6-6-5-2 Construction Requirement

(1) Surface Preparation of Concrete

Surface preparation shall be conducted by using electric disc grinder and/or brush.

(2) Material Handling

After mixing base resin and hardener, protective coating shall be applied to the surface within hardening period of about 3 hours.

(3) Application of Protective Coating

Apply 1 to 3 coats, normally.

(4) Quality Control and Inspection

The contractor shall conduct a quality control program that includes, but 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 protective coating application.
- Inspection of all work in progress to ensure work is being done is in accordance with DPWH Standard Specifications, and approved manufacturer's instructions.
- Inspection of all work completed including verification of all repairs for objective surface.

6-6-6 Measurement and Payment

6-6-6-1 Basis of Measurement

The method of measurement to determine payment for protective coating shall be based on the total applied area, as identified by the Engineer.

6-6-6-2 Basis of Payment

The quantity, measured as prescribed above, shall 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 protective coating.

CHAPTER 7 REPAIR OF STEEL BRIDGE SUPERSTRUCTURE

7-1 REPAINTING

7-1-1 Description of Repairing Method

The service life of steel bridges could be expected to exceed 50 years if its surface is kept in good protection using suitable paint coating. However, if corrosion occurs, repainting is the only restoration and effective method for steel structures. Before repainting, the surface, should at first be washed with fresh water to remove any salt from sea water environment. Relevant surface preparation shall be applied for the corroded areas to remove rust. Preparation for steel surfaces consists of two different grades of surface treatment for repainting, depending on rust conditions and type of paint, as shown in Table 7-1.

Table 7-1 Type of Repainting

Defects	Type of Paint	Photography	Rust Condition
Repaint	Epoxy Zinc Rich Primer and Polyurethane Aluminum Paint		Corrosion is very severe and coating film is not visible. 1st grade surface preparation is necessary.
	Modified Epoxy Polyimide Paint and Polyurethane Aluminum Paint		Corrosion is severe and coating film is visible but almost deteriorated due to corrosion. 2nd grade surface preparation is necessary.

The polyurethane aluminum paint shall be applied as intermediate and top coat for all steel plate surfaces.

7-1-2 Application Criteria

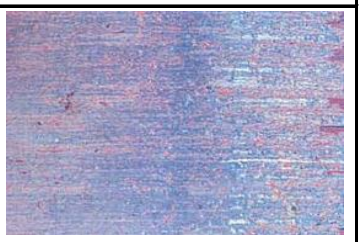
This repair method shall be applied when affected surface area is over 30%.

The 1st grade surface preparation shall be applied if the rust is very severe and coating film is not visible. The 2nd grade surface preparation shall be applied if the rust is severe and coating film is visible but almost deteriorated as shown in Table 7-2.

The 3rd and 4th grade surface preparation are not intended for repainting. However, these are carried out for application of special anti-corrosion paint which has strong adhesion to steel surface.

Additional primer coating shall be applied for bottom flanges, which are usually subjected to severe corrosion.

Table 7-2 Preparation Grades of the Surface of Corroded Steel Plate

Grade	Rust Conditions	Working Process	Photography (After Preparation)
1st Grade	Corrosion is very severe on steel surface and coating film is not visible due to corrosion. Affected surface area is over 30%	Old coating film, red rust and black rust are completely removed and revealed steel colour with sand blasting or shot blasting.	
2nd Grade	Corrosion is severe on steel surface and coating film is visible but almost deteriorated due to corrosion. Affected surface area is over 30%	Old coating film, rust is completely removed and revealed steel colour with disk grinder.	
3rd Grade	Corrosion is partially severe on steel surface and coating film is almost visible but partially deteriorated due to corrosion. Affected surface area is 20 to 30%	Old coating film, rust is removed and partially revealed steel colour with scraper and wire brush.	
4th Grade	Corrosion is partially visible but not severe. Peel-off of Coating film is partially visible. Affected surface area is 10 to 20%	Old coating film, rust is removed with disk grinder, scraper and wire brush.	

7-1-3 Work Sequence

(1) Scaffoldings

Scaffoldings for safe and efficient repainting works shall be provided for the whole bridge. Chain or wire ropes shall be attached to bottom flanges or stiffeners to tie the supporting timber or steel pipes, which serve as framing for the wooden planks. If sand blasting is required, steel girder shall be covered with plastic sheet to avoid pollution impact to surrounding soil and water.

(Scaffolding)

(Environment Protection)

(2) Preparation of Steel Surfaces

As first step, the steel bridge shall be washed with fresh water. All adhering rust, scale, dirt, grease or other foreign material shall be removed using a disc grinder or steel wire brush, depending on required surface preparation.

(3) Filling Voids

During steel surface preparation, any existing voids are filled with epoxy putty, especially if the severely corroded surface has lost significant thickness.

(4) Painting

Paint is usually applied on the steel surface using paint brush and paint roller, to ensure smooth and flat surface. It should be strictly executed to keep a continuous, uniform film of specified thickness. Paint consists of one layer of primer and two layers of polyurethane aluminum paint.

Primer

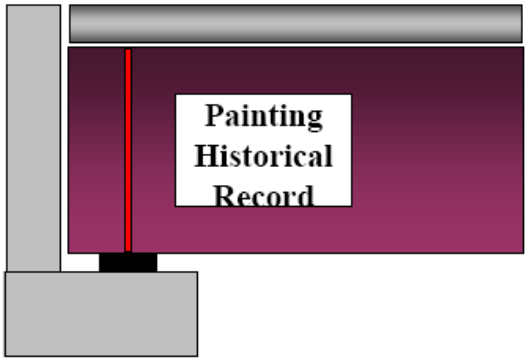
Paint (2 Layer)

(5) Checking of Paint Thickness

Measure coating film thickness using Paint/Coating Thickness Meter.

(6) Historical Record Marking

It is important to mark on the bridge surface, the Painting Historical Record. This shall be marked on web plate, near the bearing, as shown in the adjacent figure.



Example:

Date of Painting Completion		August 28,2008
Surface Preparation		2nd Grade
Paint Name	1st Coat : Primer	Modified Epoxy Polyimide Paint: Ph** GUARD** 75 μ
	2nd Coat : Primer (For Lower Flange only)	Modified Epoxy Polyimide Paint: Ph** GUARD** 75 μ
	3rd Coat : Middle Coat	Polyuréthane Paint : Ph** MA*** 50 μ
	4th Coat : Top Coat	Polyuréthane Paint : Ph** MA*** 50 μ
Paint Maker Company Name		Philip********* Paint***** Company
Painting Company		Phil** Paint** Works Company

7-1-4 Required Materials and Tools/Equipment

7-1-4-1 Required Materials

- Epoxy zinc-rich primer
- Modified epoxy polyimide paint
- Polyurethane Paint
- Thinner

7-1-4-2 Tools/Equipment

- High-pressure water jet spray
- Water tank

- Generator
- Disc grinder
- Sand blast machine
- Air compressor
- Wire brush and scraper
- Paint roller and Paint brush

Photo 7-1 Sand Blast Compressor

Photo 7-2 Sand Blast Spray Gun

7-1-5 Specifications

7-1-5-1 Material Requirement

The Specification of repainting for each of the two cases of surface preparation shall conform to the requirements in Table 7-3 and Table 7-4 or equivalent ASTM Standard.

Table 7-3 Specification of Repainting for 1st Grade Surface Preparation

Function	**Description**	**DFT(μ)**	**Test Method**	**Painting Interval**
Surface Preparation	Near white Blast Cleaning should be done to remove paint, rust, scale, dirt, grease or other foreign matters. Solvent cleaning by lacquer thinner to remove dirt, oil, grease and other contaminants. All surfaces to be painted must be dry and free from dust. (SSPC-SP10)			4 hrs
1st Coat: Primer	Epoxy Zinc Rich Primer (SSPC-Paint No.20)	75	ASTM D520	8 hrs
2nd Coat : Top Coat (For Lower Flange Plate)	Epoxy Zinc Rich Primer (SSPC-Paint No.20)	75	ASTM D520	8 hrs
3rd Coat: Intermediate Coat	Polyurethane Paint （SSPC-Paint No.36）	50	ASTM D16,Type V polyurethane	4 hrs
4th Coat: Top Coat	Polyurethane Paint (SSPC-Paint No.36）	50	ASTM D16,Type V polyurethane	4 hrs

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

Table 7-4 Specifications of Repainting for 2nd Grade Surface Preparation

Function	Description	DFT(μ)	Test Method	Painting Interval (Hr)
Surface Preparation	Power Tool Cleaning to remove existing paint, rust, scale, stains and other foreign matters. Solvent cleaning by lacquer thinner to remove dirt, oil, grease and other contaminants. All surfaces to be painted must be dry and free from dust.(SSPC-SP10)			4
1st Coat: Primer	Modified Epoxy Polyimide Paint (SSPC-PS13.01)	75	ASTM D1652	8
2nd Coat : Top Coat (For Lower Flange Plate)	Modified Epoxy Polyimide Paint (SSPC-PS13.01)	75	ASTM D1652	8
3rd Coat: Intermediate Coat	Polyurethane Paint （SSPC-Paint No.36）	50	ASTM D16,Type V polyurethane	4
4th Coat: Top Coat	Polyurethane Paint （SSPC-Paint No.36）	50	ASTM D16,Type V polyurethane	4

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

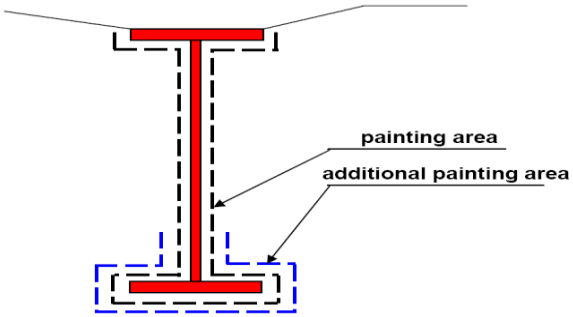


Figure 7-1 Repainting Area

7-1-5-2 Construction Requirement

(1) Preparation of Steel Surface

All surfaces to be painted shall be thoroughly cleaned of all rust, dirt, oil or grease, and other foreign substances. Additionally, paint surfaces shall be lightly sand blasted or sanded prior to painting, to enhance adhesion. The method of surface preparation shall conform to subsection 7-1-2 or shall be as recommended by the coating manufacturer.

The contractor shall furnish and install necessary protective devices at the site of the cleaning and surface preparation to ensure complete protection of public and properties adjacent to the blast cleaning abrasives. The type, quantity, and placement of protection must be submitted for Engineer's approval, before cleaning and painting operations commence. The contractor shall have sufficient reserved quantity of protective devices, and shall be prepared to install same, allowing for unexpected variations in wind and other contingencies. Cleaning and surface preparation shall not proceed unless the required protective devices are in place.

(2) Painting

The painting will be in accordance with the DPWH Standard Specifications, Item 411.3.6, Painting.

(3) Quality Control

The Contractor is required to conduct and document quality control inspection of the cleaning and painting operations including, at a minimum, measurements of ambient conditions, surface profile, surface cleanliness, coating material acceptability, dry film thicknesses, and visual inspection for coating defects. The data shall be recorded in a Contractor's log maintained at the painting site.

The measurement of dry film thickness shall be measured by as following manner.

(a)Frequency: After every application of succeeding paint type.

(b)Procedure: Determine painted surface area.

One (1) lot should be not more than 500m^2.

Pick at least 25 random points representing the lot.

Thickness of paint at each and every point should be taken 5 times.

Thickness of paint should be tested.

7-1-6 Measurement and Payment

7-1-6-1 Method of Measurement

The method of measurement as basis for payment shall be in total square meters of steel surface area, as identified by the Engineer.

7-1-6-2 Basis of Payment

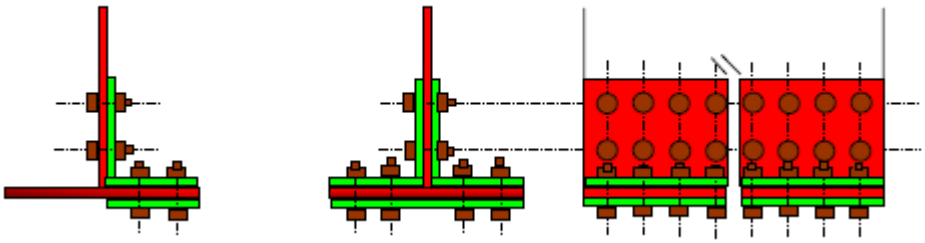
Repainting works shall be paid for at a unit price per square meter, complete in place, which include all materials, containers, equipment, tools, labor, service advisor and work incidental for the repainting of the structure. Any indirect cost item shall not be paid separately. If scaffoldings and protective devices are provided, corresponding costs shall be deemed included in the square meter unit price.

7-2 STEEL PLATE ADDING

7-2-1 Description of Repair Method

Steel girders near sea shores are prone to corrosion which could accelerate, consequently leading to section loss, especially of the bottom flange plates and sections near the bearings.

There were incidences where existing steel bridges near sea shores were not maintained for around 20 years. Severe corrosion had occurred causing significant section loss and defective bolt holes. In such cases, strength of the lower flange section shall be restored considering the original designed area. This is implemented by adding steel plates or angles connected with high tension bolts (HTB) as shown in Figure 7-2.



(1) One side of lower flange (2) two sides of lower flange

Figure 7-2 Adding Steel Plate and Angular Plates

Existing bottom flanges with section loss shall be provided with a flat plate at its bottom face, bolted with HTB to angular (bent plates) placed at the junction of web and bottom flange. The suggested total thickness of the plates shall be approximately 9 mm.

7-2-2 Application Criteria

In order to restore the lost strength, additional steel plates shall be installed to the portion of existing steel, where section loss is more than 20%. This repair method shall be further supplemented by repainting or special anti-corrosion coating (refer to relevant sections in 7-1 above).

7-2-3 Work Sequence

(1) Scaffoldings

Scaffolding for safe and efficient repainting works shall be provided. Chain or wire ropes shall be attached to bottom flanges or stiffeners to tie the supporting timber or steel pipes, which serve as framing for the wooden planks.

(2) Surface Preparation

All surfaces to be provided with additional steel plates shall be thoroughly cleaned of all rust, dirt, oil or grease, and other foreign substances. Moreover, surfaces to be painted shall be lightly grinded to increase adhesion of the new paint required. The grade of surface preparation shall conform to subsection 7-2 for repainting system or shall be as recommended by the manufacturer.

(3) Surface Treatment

Surfaces of corroded steel plate may have holes and dents. Reduction of original thickness of the steel plate could as well vary. After surface preparation, epoxy putty is applied to level the surface of the existing steel plate and recover its original thickness and shape.

(4) Holes for HTB

Templates for bolt holes for the additional flat plate or angular plate, which shall be fabricated at the factory, shall be prepared based on the actual positioning required at site. Holes for the HTB are drilled through the plates using portable electric drill or electric coring drill. Suggested diameter of hole is 25 mm to 27 mm, intended for M22 HTB.

(5) Assembling flat plate and angular plate

Additional flat plates and angular plates are placed on the actual bottom flange locations for purposes of installing HTB. After installation, each HTB is first fastened with electric fastener. The details of fastening HTB shall conform to Subsection 7-4-3.

(6) Epoxy Caulking

Small gaps found between the new plate and existing steel plate shall be filled with epoxy caulking.

(7) Tightening High Tension Bolts

After the first fastening as per (5) above, yellow mark is painted on each HTB in order to identify the original orientation. HTB are finally tightened using rotation angle method as means of quality control to maintain design tension stress. The limit of rotation angle for tightening shall be 120°±30° from the marking.

(8) Painting

After installation of the steel plates and HTB are completed, polyurethane aluminum paint is applied. Portions of steel plate where section loss or severe corrosion are found shall be painted with special anti-corrosion paint as protection against further rusting.

(9) Historical Record Marking

Historical record for the repair measure performed should be marked on the web plate near the bearing as shown in Sub-section 7-1-3 (7).

7-2-4 Required Materials and Tools/Equipment

7-2-4-1 Required Material

- Flat plate and angular plate
- High tension bolt (HTB)
- Epoxy putty

7-2-4-2 Required Equipment/Tools

- Electric drill,
- Fastening wrench,

7-2-5 Specification

7-2-5-1 Material Specifications

Specifications for related materials for this repair method are as follows:

- Flat/Angular plates (JIS G3101, 3106, ASTM A36 or equivalent)
- HTB (JIS B 1186, ASTM A325 or equivalent)
- Epoxy putty (refer to 5-5-5-1, CFP Bonding to Concrete)
- Polyurethane Aluminum Paint (refer to Section 7-1 Repainting).
- Special Anti-Corrosion Paint (refer to Section 7-5).

The type of test shall be applied tensile strength test for HTB to be approved by the Engineer.

7-2-5-2 Construction Requirement

(1) Surface Preparation

The Engineer will instruct the Contractor on the required grade of surface preparation. Regardless of the severity of corrosion, section loss to be mainly considered shall be limited to the bottom flange and edges of girders near the bearings. The contractor shall submit related shop drawings for Engineer's approval.

(2) Material Handling

Templates for bolt holes shall be provided for the steel plates fabricated at the factory, based on required actual positioning at site.

Prior to fabrication, the contractor should submit shop drawings for Engineer's approval.

(3) Epoxy Putty

(This work item for achieving smooth surface between steel plates is optional.)

- Mix two parts of epoxy putty until the mixture is homogenized.
- Apply the putty to smoothen the gap between the steel plates

(4) Holes for HTB

Holes for the HTB are drilled through the steel plates using portable electric drill or electric coring drill. Suggested diameter of hole is 25 mm to 27 mm, intended for M22 HTB.

7-2-6 Measurement and Payment

7-2-6-1 Method of Measurement

Method of measurement for this repair method shall be the total weight of the steel plates and HTB, verified and approved by the Engineer.

7-2-6-2 Basis of Payment

Payment shall be based on unit price per kg. The unit price shall include all materials, containers, equipment, tools, labor, service advisor and incidental items for these works. Any indirect cost item shall not be paid separately. Such costs shall be deemed included in the per kg price.

7-3 CARBON FIBER PLATE BONDING TO STEEL

7-3-1 Description of Repair method

Steel girders near sea shore are prone to corrosion which could accelerate, consequently leading to section loss, especially of the bottom flange plates and sections near the bearings.

Repair method using carbon fiber plate (CFP) bonding to steel plate provides the same function as the additional steel plates presented in previous section. Repair method for adding steel plates involve complicated steps such as fabrication of the steel plates in the factory, cut and drill holes for HTB to existing bridge plate in the field and assembling of the additional steel plate. On the other hand, CFP method involves simple application of bonding to steel bridge surface using epoxy resin adhesive. In case of section loss or defective holes, the purpose of bottom flange repair shall be to restore the original strength of the section by installing required area of CFP as shown in the example in Figure 7-3 and Figure 7-4;

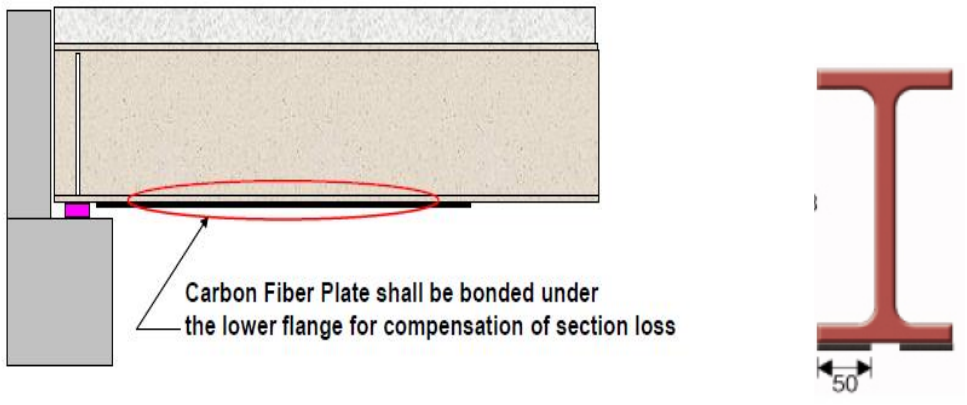


Figure 7-3 CFP Added at Bottom Flange

Figure 7-4 Carbon Fiber Plate Size

7-3-2 Application Criteria

In order to restore the lost strength, CFP shall be installed at the portion of existing steel where section loss is more than 20%. This repair method shall be further supplemented by repainting or by application of anti-corrosion coating (refer to relevant sections in 7-1 above).

7-3-3 Work Sequence

(1) Scaffoldings

Scaffolding for safe and efficient repainting works shall be provided. Chain or wire ropes shall be attached to bottom flanges or stiffeners to tie the supporting timber or steel pipes, which serve as framing for the wooden planks.

(2) Surface Preparation of Steel Plate

All surfaces to be provided with carbon fiber plates shall be thoroughly cleaned of all rust, dirt, oil or grease, and other foreign substances. Moreover, surfaces to be painted shall be lightly grinded to increase adhesion of the new paint required. The grade of surface preparation shall conform to subsection 7-2 for repainting system or shall be as recommended by the manufacturer.

(3) Adjustment of Unevenness with Putty

Surfaces of corroded steel plate may have holes and dents. Reduction of original thickness of the steel plate could as well vary. After surface preparation, epoxy putty is applied to level the surface of the existing steel plate and recover its original thickness and shape.

Epoxy putty coating shall be applied after steel surface preparation. The surface where the CFP will be placed shall be smoothened using #60 - #100 sandpaper.

(4) Application of Epoxy Resin for Undercoat

Using a roller, epoxy resin shall be applied as adhesive to bond to CFP, thus forming a molded composite through impregnation into the CFP.

(5) Carbon Plate Bonding

An epoxy based adhesive is applied to the CFP with molder to bond. To reduce formation of voids, the adhesive is spread forming a curved profile that measures 3 mm at the centre and 1 mm at the edges. CFP should be installed by applying manual uniform pressure along the longitudinal centerline.

(6) Squeezing of Strip to Entrapped Air

For effective impregnation, entrapped air is squeezed out of the strips using roller, before the adhesive sets.

7-3-4 Required Materials and Tools/Equipment

7-3-4-1 Required Materials

- Epoxy putty
- Carbon fiber plate

7-3-4-2 Required Tools/Equipment

- Electric disc grinder
- Generator
- Wire brush, scraper etc.,

7-3-5 Specifications

7-3-5-1 Material Requirement

CFP is made from pre-laminated carbon fiber. Each roll unit roll of CFP has width: 50 mm; thickness: 1 mm, 1.5 mm, and 2 mm; and length: 50 m. The specification shall be in accordance with the following or equivalent ASTM specifications.

High-Elasticity (ML) type shall be applied to steel bridges where section loss need to be compensated.

Table 7-5 Strength of CFP Plate

Property	Test Method	Unit	Specification
Carbon fiber plate weight		g/m^2	1200
Carbon fiber plate density		g/cm^3	1.6
CFP Tensile Strength	JIS K 7073/ASTM D3039	N/mm^2	2400
Tensile Bond to Concrete Dry Wet	JHS-411/ JIS K6852/ASTM C882	N/mm^2	 ≥ 2.0 ≥ 2.0

The material shall undergo tensile strength test for CFP to be approved by the Engineer.

Epoxy adhesive shall conform to the following or equivalent ASTM Specifications.

Table 7-6 Epoxy Adhesive (Putty) for CFP Bonding with Steel

Property	Test Method	Unit	Specification
Specific Gravity	JIS K7112/ASTM D792	−	1.7±0.10
Flexural Strength	JIS K7203/ASTM D790	N/mm^2	45
Compressive Strength	JIS K7208/ASTM D695	N/mm^2	70
Modulus of Elasticity	JIS K7208/ASTM D695	N/mm^2	4000
Tensile Strength	JIS K 7113/ASTM D638	N/mm^2	25
Tensile Shear Bond	JIS K 6850/ASTM D1002	N/mm^2	15
Bond Strength to CFP & Steel	JIS K5400/ ASTM D7234	N/mm^2	3.5

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

CFP and Epoxy adhesive (Putty) should be selected in accordance with manufacturer's instructions.

7-3-5-2 Construction Requirement

(1) Surface Preparation

All surfaces to be provided with CFP shall be thoroughly cleaned of all rust, dirt, oil or grease, and other foreign substances and smoothened using disc grinder, hammer, scraper or brush. If the surface is not flat enough for the installation of CFP, epoxy putty shall be applied to achieve required even finish.

(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 conformance with Manufacturer's recommendations and instructions.

(3) Prime Coat

Contact surface shall be dry prior to application of coating primer. The primer should be formulated and compatible with the carbon fiber material and should not be applied during rain, storms or when the air is misty or when in the opinion of the Engineer, weather condition remains unsatisfactory.

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

(4) Putty Application

This work involves application of epoxy putty above the primer coated steel surface, using trowel or spatula, to achieve a smooth finish. The putty shall be applied after the primer is tack-free.

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

(5) Application of Epoxy Resin for Undercoat

The Contractor shall submit for the Engineer's 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 with ambient temperature and manufacturer's recommendation in 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^2

(6) Carbon Fiber Plate Application

CFP shall be cut to 4 to 6 m length and applied 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^2
- 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) Quality Control and Inspection

The Contractor shall conduct a quality control program that includes, but 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 surface preparation carried out prior to CFP application.
- Inspection of work in progress to ensure work is being done in accordance with DPWH Standard Specifications and approved manufacturer's instructions.
- Inspection of all work completed including verification of all repairs to check for debonding and correction of any defective work.
- After allowing at least 24 hours for the 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 the manufacturer's recommendations. The Contractor shall conduct adhesion testing of the fully cured CFS and CFP installation using direct pull-off tests, at locations determined by the Engineer. Failure at the bond line at tensile stress below 14 kgf/cm^2 (200 psi) will be cause for rejection of the repair. A minimum of two pull-off tests per system (span) shall be performed.

7-3-6 Measurement and Payment

7-3-6-1 Method of Measurement

The method of measurement for this repair method shall be by linear meter of CFP, checked and approved by the Engineer.

7-3-6-2 Basis of Payment

CFP bonding work shall be paid for at a unit price per linear meter. The unit price shall include all materials, containers, equipment, tools, labor, service advisor and required incidentals for the work. Any indirect cost item shall not be paid separately. Such cost shall be deemed included in the unit price.

7-4 TIGHTENING / RETIGHTENING OF HIGH TENSION BOLT

7-4-1 Description of Repair Method

Missing or loosened high tension bolt (HTB) connection for steel girders are either replaced or retightened in the field during maintenance inspection conducted. Before tightening the bolts, surface preparation of steel plate shall be carried out by removing dust, grease and water, and then repainted. Missing bolts, severely corroded bolts found at top flanges shall be replaced as per method presented in Table 7-7. Damaged bolts found to exhibit delayed fatigue fracture (Photo 7-3) need to also be replaced considering the method presented.

Photo 7-3 Sample bolt with Delayed Fatigue Fracture

Table 7-7 Replace Method of HTB in Girder Top Flange

Item No. / Method	No.1	No.2	No.3
	Replace Bolt only	**Chip-off haunch**	**Break Deck Slab**
Outline of method	**Remaining Nut still used**  **Replace Bolt only**		
	・Remove severely corroded HTB from top flange ・Rotation angle method is applied to fasten HTB as quality control	・Chip of concrete from ① or② shown ・Replace bolts and nuts ・Pour non-shrink mortar at chipped off locations	・Break deck slab from top surface ・Replace bolts and nut ・Pour non-shrink mortar for broken portion of the deck

7-4-2 Application Criteria

This repair method is applied to for missing bolts, severely corroded bolts and for loosened fasteners exceeding 10% of the total number of bolt per location.

7-4-3 Work Sequence

(1) Remove HTB

If the HTB is found severely corroded, it shall first be removed from the plate. Removal shall be carried out using electric drill, hammer, wrench, and spanner with long handle. If removal using said devices remains difficult, the bolt shall be cut using acetylene gas.

Photo 7-4 Electric Fastener for HTB

(2) Surface Preparation

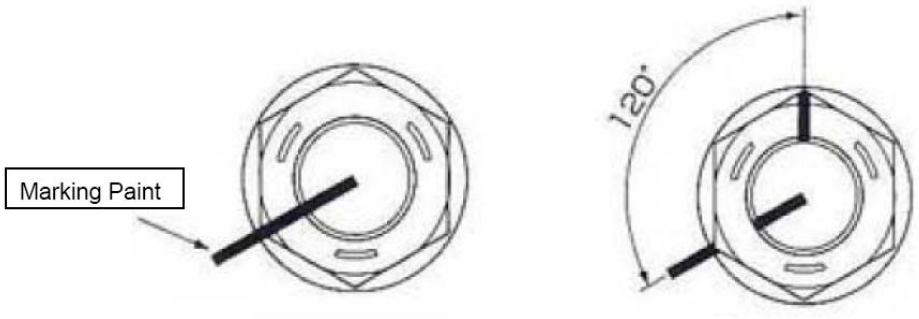
After rinsing with water, all adhering rust, scale, dirt, grease or other foreign material shall be removed from the steel plate.

(3) Fastening HTB

After installation of HTB, each shall be initially fastened using electric fastener. Yellow marking is then painted on each HTB in order to distinguish the original orientation.

(4) Quality Control of HTB fastening

HTB are finally fastened using Rotation Angle Method as a means of quality control to meet the required design tensile stress. The fastening rotation angle shall be 120°±30° from the location of the yellow marking.



1st Fastening Final Fastening

Figure 7-5 Method of HTB Fastening

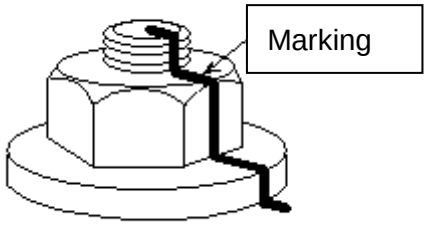


Figure 7-6 Marking

(5) Surface Preparation

After fastening all the HTB, grease or other oil material shall be removed using solvent material. New HTB shall be covered with grease to control rotation friction.

(6) Painting

If repainting of the finally fastened HTB is necessary, refer to Section 7-1 and 7-5 for Polyurethane Aluminum Paint and Special Anti-corrosion Paint, respectively, for the required appropriate paint material.

7-4-4 Required Materials and Tools/Equipment

7-4-4-1 Required Materials

- HTB (22 mm or 7/8 in. diameter)
- Nuts
- Plain hardened washers

7-4-4-2 Required Tools/Equipment

- Torque wrench
- Electrical Impact wrench, Special fastener for HTB,

7-4-5 Specification

For HTB, refer to ITEM 712 of the DPWH Standard Specifications, particularly 712.1.9 specifying AASHTO M164 (ASTM A325)

7-4-6 Measurement and Payment

7-4-6-1 Method of Measurement

The quantity of HTB shall be measured by kilograms, checked and approved by the Engineer.

7-4-6-2 Basis of Payment

The quantities, measured as prescribed above, shall be paid for at a contract until price for several pay items which shall include full compensation for furnishing, preparing, fabricating, transporting, placing and assembly.

7-5 SPECIAL ANTI-CORROSION PAINT

7-5-1 Description of Repair Method

For 24 years, special anti-corrosion paint was applied to maintain good surface condition of bridges in Japan situated in severely active environment, subjected to wind-borne sea water spray. It is a well-recognized material, proven effective based on several environment tests conducted in Japan. As an example, field tests conducted for the Shimonoseki Fishing Park in Japan shows that the structure remains in good condition, without requiring any major strengthening measures. Currently, it is still subjected to actual field examination to determine the limit of maximum durability of the materials, without repainting. It was initially observed that progressive rust was arrested after application of high alkaline atmosphere special anti-corrosion paint.

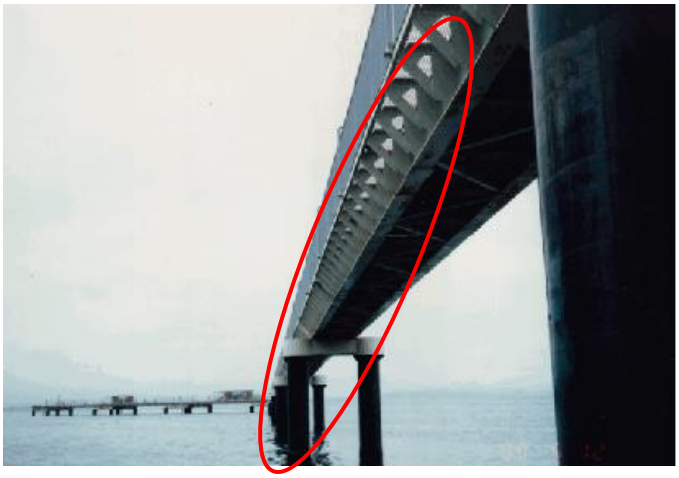


Photo 7-5 Simonoseki Fishing Park in Japan in Use since 1984

As a minimum coating requirement the total special anti-corrosion paint weight should exceed 1.0kg/m^2 for two coats.

7-5-2 Application Criteria

As rust protection, anti-corrosion paint shall be applied to the portion of steel plate that has section loss of more than 10% but less than 20%. This repair method is also applied in combination with repair method of Section 7-1

7-5-3 Work Sequence

(1) Scaffolding

Scaffolding shall be provided below the bridge or at bridge sides, to facilitate painting works.

(2) Preparation of Steel Surface

After rinsing with water, all adhering rust, scale, dirt, grease or other foreign material shall be removed to clean the identified surfaces.

The 3rd Grade surface preparation (Table 7-2) is commonly adopted for the steel surface, using wire brush and electric disc grinder. Existing undamaged coating film may be maintained. It is also not necessary to completely remove rust using the disc grinder, as this will be arrested after application of the special anti-corrosion paint.

Before surface preparation

By hand scraper

By electric scraper

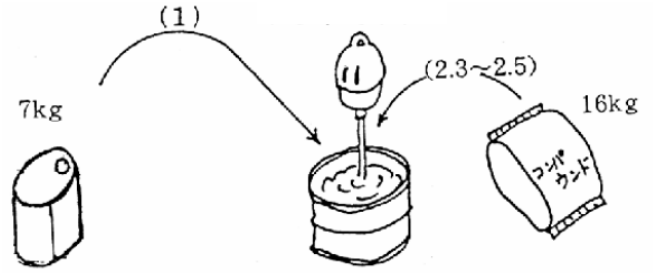
After completed surface preparation

(3) Mixing paint

Proper mixing of compound and emulsion is vital to attain expected quality of this special paint. Usually, a mixing ratio of 1: 2.3 is required between emulsion and compound. Hence, using a hand mixer device, a 7 kg emulsion shall be mixed with 16 kg compound.

During the mixing process, no water shall be added to the mixture. If the mixed powder becomes dry while being stored, emulsion shall be added to maintain consistency.

（Hand mixer）



Emulsion **Compound**

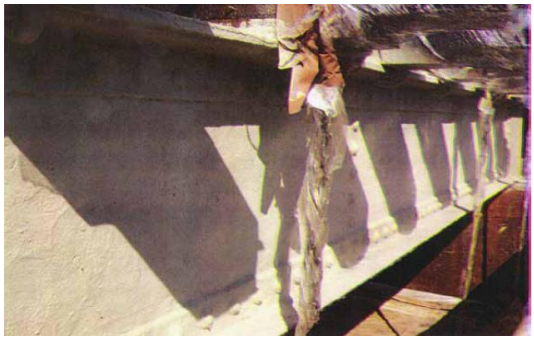
Figure 7-7 Mixing Materials for Special Anti-Corrosion Paint

(4) Painting

To avoid negative impacts to environment at the site as well as appreciate savings on materials, the paint is usually applied using either paint brush or roller. Hand painting with brushes as a traditional method, does not require artificial supply of energy. It should however be carefully executed and strictly controlled to maintain the required quality of coating film thickness. To ensure consistency, the coating film thickness shall be measured under dry condition, using a thickness gauge.

If the applied paint is damaged by electric grinder while removing some dust particles, over coating of the special anti-corrosion paint shall be provided.

1st layer painting by spray gun



after completed 2nd painting

Shaded finish (blue color as example in above photo) can be applied as top coating for aesthetics purpose only, if required

7-5-4 Required Materials and Tools/Equipment

7-5-4-1 Required Materials

- Emulsion
- Compound.

7-5-4-2 Required Tools/Equipment

- Hand mixer
- Paint roller and paint brush
- Wire brush, electric grinder
- Portable generator

7-5-5 Specifications

7-5-5-1 Material Requirement

The total quantity of Special Anti-Corrosion Paint shall exceed 1.5kg/m^2 for two coating application.

- 1st layer Special Anti-Corrosion Paint : 250μm
- 2nd layer Special Anti-Corrosion Paint: 250μm

Physical and material test specifications are mentioned in below Table 7-8.

Table 7-8 Specification of Special Anti-Corrosion Paint

Property	Test Method	Unit	Specification
Adhesive test	JIS A6909/ASTM D7234	N/mm2	7days 1.0, 28days 1.5
Elongation	ASTM C190	%	7days 0.40, 28days 0.40
Saltwater test	JIS K5600/ASTM D6943		no defection

The materials should be selected in accordance with manufacturer's instruction.

7-5-5-2 Construction Requirement

(1) Preparation of Steel Surface

Defective steel surfaces due to severe corrosion shall be prepared prior to painting. The surface shall be washed with fresh water. Existing rust shall be removed using disk grinder, hammer and scraper in accordance with 3rd grade surface preparation. The surface preparation shall be accepted by the Engineer before applying special anti-corrosion paint.

(2) Mixing of Materials

Special anti-corrosion paint shall be formed by mixing 2.3 parts compound and 1 part emulsion. The contractor shall present for Engineer's approval the boxes and containers of compound and emulsion required for the area to be painted. If the mixed paint hardens after some time, a minimal amount of emulsion shall be added to stabilize mixture consistency. Water shall never be added to the mixture.

(3) Painting Condition

Similar to ordinary paint, application of special anti-corrosion paint shall be done under dry condition. The 2nd layer paint shall be applied to the 1st layer, when the latter has already dried.

(4) Curing

The coating film will completely dry within a day, under a temperature of 30℃. During rainy season, drying time is more 2 days. Nevertheless, once the coating dries, water is not expected to affect the surface.

(5) Inspection

The contractor shall submit to the Engineer emptied used boxes and containers, justifying completion of works. These shall also be supplemented with pictures of the completed work. The paint film thickness shall be measured using thickness gauge to verify consistency of thickness. The minimum thickness allowed shall be 70% of the required value, similar to the quality control adopted for ordinary painting system.

7-5-6 Measurement and Payment

7-5-6-1 Method of Measurement

The method of measurement shall be by square meters of steel surfaces cleaned, painted and accepted by the Engineer.

7-5-6-2 Basis of Payment

This work shall be paid for at a unit price per square meters of "Special Anti-Corrosion Paint" item, complete in place, which shall include all materials, containers, equipment, tools, labor, service advisor and work incidental for the painting of the structure. If scaffoldings need to be installed, it shall be deemed included for the price per square meters. Any other indirect cost item shall not be paid separately. This shall be deemed included in the square meter price.

CHAPTER 8 REPAIR OF BRIDGE EXPANSION JOINT

8-1 ASPHALTIC PLUG JOINT

8-1-1 Description of Repair Method

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 sealant asphalt, the sealant is easily damaged due to traffic load and aging.

The usual gap between concrete edges is around 20 mm considering temperature in the Philippines as 27°C ± 10°C. The movement of a 20 m bridge span due to changes in temperature is 12 × 10-6 / °C × 20 m × (± 10°C) = ± 2.4mm and the movement of the same span due to traffic load is approximately less than 5 mm. Total movement of a20 m span RCDG bridge is below ± 10 mm. With these considerations, the most suitable repair measure for damaged asphalt sealant is the installation of asphaltic plug joint.

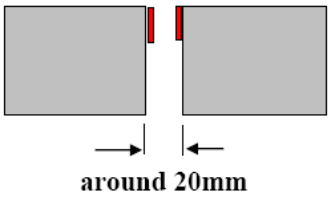


Figure 8-1 Sealant Asphalt Joint

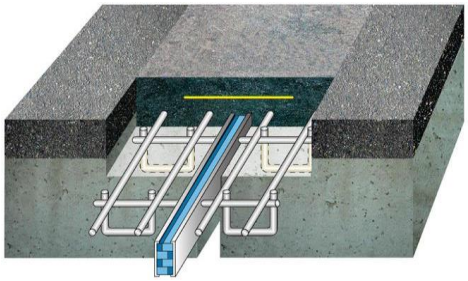


Figure 8-2 Type of Asphaltic Plug Joint

Photo 8-1 Cleaning of the gap

Photo 8-2 Flexible Asphalt pouring

8-1-2 Application Criteria

Asphaltic plug joints are mainly applied on RCDG bridges and steel girder bridges on fixed bearings. This repair method shall be implemented 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.

8-1-3 Work Sequence

(1) Dismantle Existing Damaged Asphalt Joint Sealant

The damaged sealant due to heavy traffic, aging, etc. shall be dismantled.

(2) Chipping surface concrete

Chip-off edges of concrete to install steel frame and to insert the form to narrow gap. (Proper gap for seamless joint is less than 25 mm.)

(3) Install steel frame

Steel frame shall be fabricated with box frame and Rebar. This frame shall be fixed by welding between Concrete anchor and rebar.

(4) Rebar Anchor

Besides intersection of rebar, the concrete anchor shall be inserted for every intersection of rebar.

(5) Pouring Flexible Asphalt

Flexible Asphalt shall be poured to the chipped off edges. The height of pouring is half of total thickness.

(6) Installation of Expansion Sheet

Expansion Sheet shall be spread on the first layer of flexible asphalt.

(7) Pouring Flexible Asphalt

Flexible asphalt (asphalt- rubber chips) shall be poured as second layer.

The surface of flexible asphalt shall not be compact or tamping until decrease the temperature.

8-1-4 Required Materials and Tools/Equipment

8-1-4-1 Material Requirement

- Steel frame (welded with anchor rebar)
- Concrete anchor with steel bar
- Expansion sheet
- Flexible Asphalt (asphalt-rubber chip, see Photo 8-3)

Photo 8-3 Sample Asphalt Rubber Chips

8-1-4-2 Required Tools/Equipment

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

8-1-5 Specification

8-1-5-1 Material Requirement

- Pre-fabricated steel frame : ASTM A36 or equivalent,

Flexible asphalt shall be based in accordance with Table 8-1.

Table 8-1 Specifications of Flexible Asphalt

Property	Test Method	Unit	Specification
Density	ASTM D1188	g/cm^3	2.26±0.05
Splitting Strength	ASTM D4123-82	N/mm^2	1.57±0.29
Deformation (Flow value)	JIS K2207 / ASTM D1559	1/100cm	140±20

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

8-1-5-2 Construction Requirement

(1) 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 frame. After chipping, the contractor shall verify the sizes and spacing of existing reinforcements.

(2) Install Steel Frame

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

(3) Pouring Flexible Asphalt

Prior to pouring, the Contractor shall submit material test results for the flexible asphalt, for approval of the Engineer.

The flexible asphalt shall be subjected to strict quality control especially for the temperature control requirements. Using mini asphalt cooker, flexible asphalt shall be cooked with minimum temperature of 180℃ and not to exceed 288^{O}C. The asphalt shall be poured on the gap until half of total thickness as first layer.

(4) Expansion Sheet

Expansion sheet shall be laid on first layer of flexible asphalt using gas burner.

(5) Pouring Flexible Asphalt

The 2nd layer of flexible asphalt shall be subjected to strict quality control especially for the temperature control requirements.

8-1-6 Measurement and Payment

8-1-6-1 Method of Measurement

The method of measurement for this method shall be by linear meter of joint length defined by the Engineer.

8-1-6-2 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.

8-2 REPLACEMENT OF EXPANSION JOINT

8-2-1 Description of Repair Method

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.

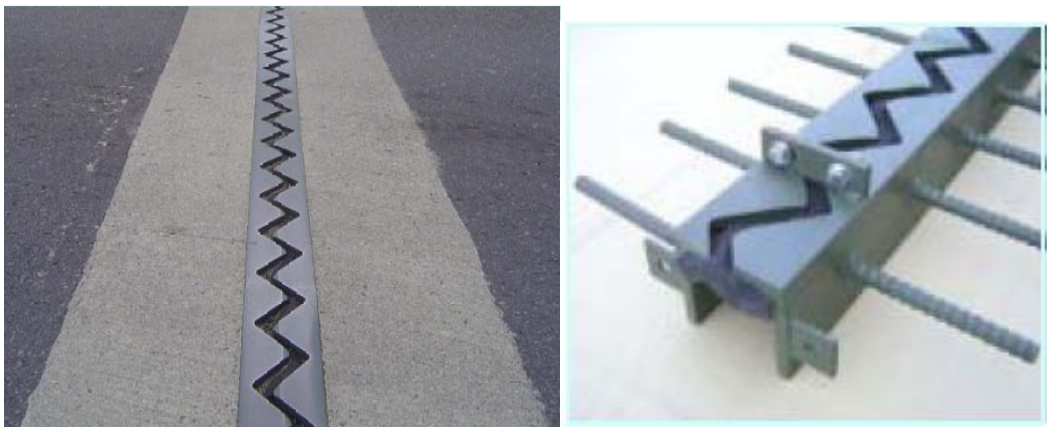


Photo 8-4 Sample of Waterproof Type Expansion Joint

8-2-2 Application Criteria

The replacement of steel expansion joint shall be implemented 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: Difference in elevation is >30mm at expansion gap
- Displacement: Pourable joint sealant maybe almost completely lost
- Cracking: Cracking on primary members especially in welded parts

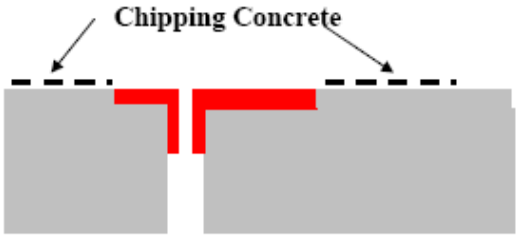
Meanwhile, replacement of rubber expansion joint shall be implemented if the following condition criteria are rated “Bad”:

- Water leakage: detected area >50%
- Abnormal Space/ Noise: Detected
- Difference in Elevation: >30mm at expansion gap
- Rupture: Rubber seal dislodged or peeled-off
- Abnormal Space/ Noise: Detected
- Deteriorated Sealant: Joint sealant maybe almost completely lost.

8-2-3 Work Sequence

(1) Cut concrete surface

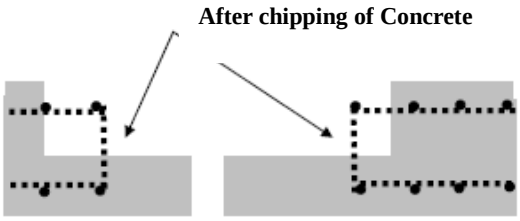
Using concrete sawing device, concrete surface shall be cut in transverse direction.



(2) Chipping off concrete/ Dismantling defective expansion joint

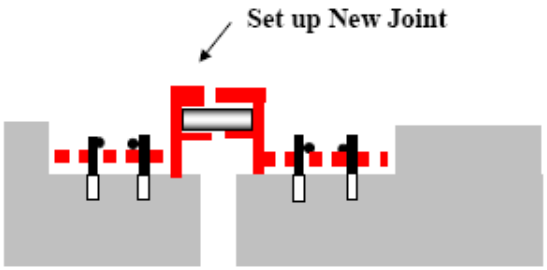
Concrete shall be continuously chipped off to achieve the required positioning for the new expansion joint. Exposed existing rebars shall remain to maintain the strength.

The damaged expansion joint shall then be dismantled after chipping off concrete



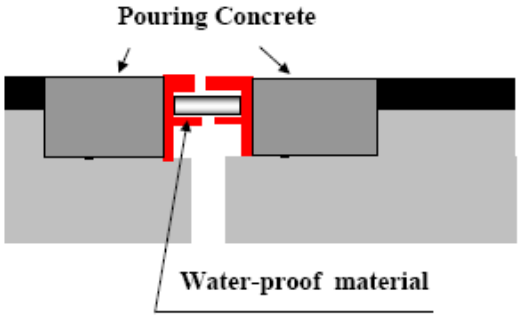
(3) Set up new expansion joint

The new expansion joint with water-proof device shall be installed. Transverse rebar (16 mm dia.) shall be fixed with mechanical anchors.



(4) Pouring Concrete

After verification measurements, concrete shall be poured, and then cured, to complete the works.



8-2-4 Required Materials and Tools/Equipment

8-2-4-1 Required Materials

- New Expansion Joint with water proof rubber
- Rebar (16 mm dia.)
- Concrete/grout

8-2-4-2 Required Tool/Equipment

- Concrete Cutter
- Electric impact hammer/small jackhammer
- Electric concrete vibrator
- Trowel

8-2-5 Specification

8-2-5-1 Material Requirement

For new expansion joint

- Steel plates, anchor bars: ASTM A36 or equivalent
- mortal/concrete: refer to 5-3-5-1 polymer cement mortal

The expansion joint rubber seal shall comply with the following specifications:

Table 8-2 Specification of Expansion Joint Rubber Seal

Property	Test Method	Unit	Specification
Tensile Strength	JIS K6251/ASTM D412	MPa	0.98(Min)
Elongation at break	JIS K6251/ASTM D412	%	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.

8-2-5-2 Construction 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 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.

8-2-6 Measurement and Payment

8-2-6-1 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.

8-2-6-2 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.

CHAPTER 9 REPAIR OF BRIDGE BEARING

9-1 REPLACEMENT OF BEARING

9-1-1 Description of Repair Method

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 bridge bearings 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. This is discussed in detail in Section 9-3 of this manual (Jack-up Girder). During replacement of the bearings, traffic may remain open but with imposed restriction on passing speed as safety precaution. The girder shall be jacked up from 5 mm to 10 mm, with one jack stroke.

Photo 9-1 Sample of Replacement Bearing

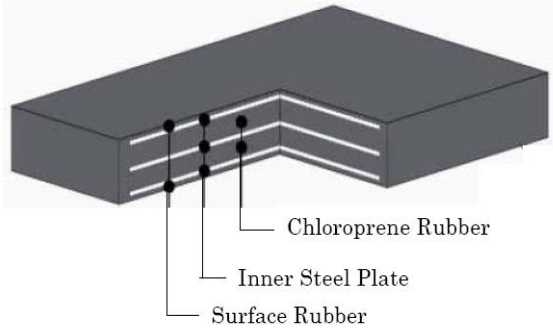


Figure 9-1 Rubber Bearing

9-1-2 Application Criteria

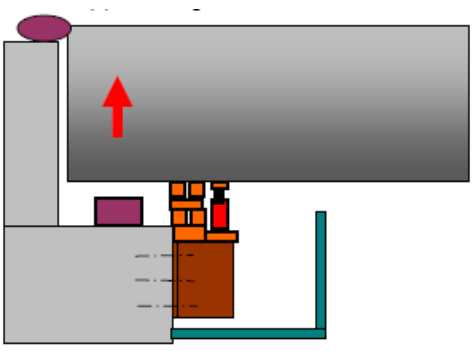
Replacement of bearing shall be implemented if existing rubber bearings already exhibited severe cracks and abnormal bulging. Old steel bearings need to be replaced especially if loose connections were observed. This repair method form part of the jack-up girder method described in Section 9-3.

The capacity of the new bearing should be the same as the old bearing, subject to approval of the Engineer.

9-1-3 Work Sequence

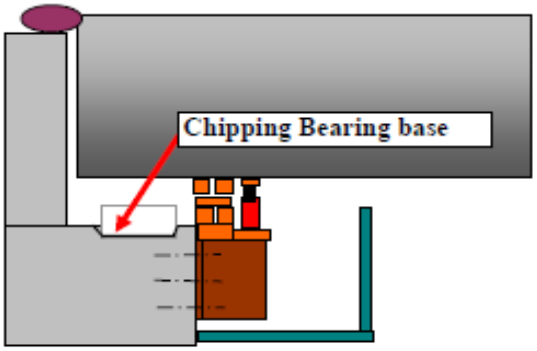
(1) Jack up girder

Jack-up girder process shall be referred to Section 9-3 of this manual. 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 below 10 mm.



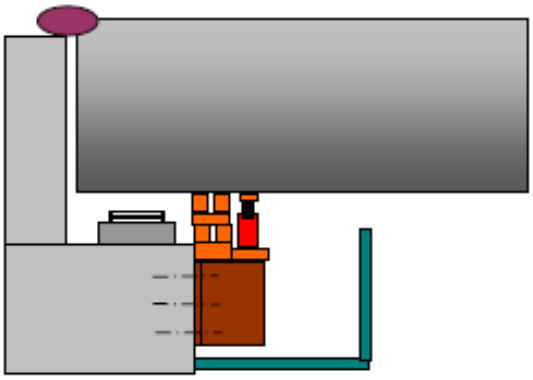
(2) Dismantle existing Bearing and chipping bearing base

After jacking-up process, chip-off concrete bearing base to remove existing bearings.



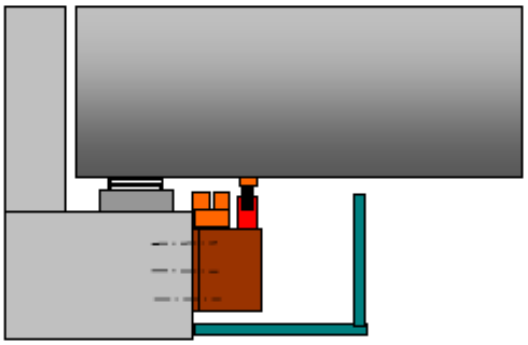
(3) Cast New Bearing Seat and Set up New Bearings

After concrete chipping and new required bed support replacement with rebar will be installed using non-shrink grout, the new bearings shall be set up at appropriate position and level. The level shall consider additional factor such as compressive displacement of elastic rubber bearing.



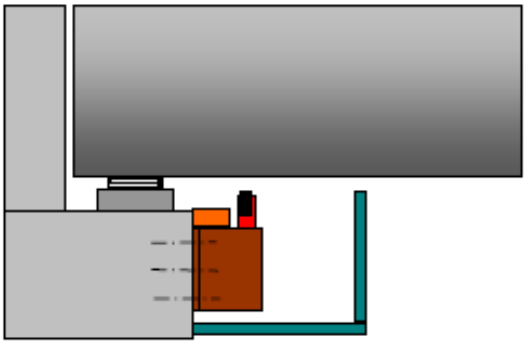
(4) Jack Down Girder after Curing

After curing of bearing be, it should be inspected to check the level and stability before thegirder is jacked down and consequently supported by the new rubber bearing. Final position and height of the new bearing shall be verified, subject to approval of the Engineer.



(5) Dismantle Jacks and Temporary Supports for the Final Work

After replacement of the new rubber bearings are accomplished, jack device and temporary supports shall be dismantled. Steel surfaces shall be painted, if found necessary.



9-1-4 Required Materials and Tools/Equipment

9-1-4-1 Required Materials

- Elastomeric bearing pads.
- Rebar
- Mortal/concrete

9-1-4-2 Required Tools/Equipment

- Hydraulic Jack
- Electrical Jackhammer
- Trowel

9-1-5 Specification

9-1-5-1 Material Requirements

(1) Bearing Pads

Elastomeric bearing pads shall be as per Item 412- (Elastomeric Bearing Pads) of the DPWH Standard Specifications and confirm to AASHTO M251.

Property	Test Method	Unit	Specification
Hardness, Durometer A	ASTM D2240	—	60±5

The material test shall be applied for Hardness test to be approved by the Engineer.

(2) Other Materials

- For Rebar, refer to Item 710 (Reinforcing Steel And Wire Rope) of the DPWH Standard Specifications
- For bearing base mortar, refer to mortar described in Section 5-4-5 of this manual.

9-1-5-2 Construction Requirement

(1) Jack up girder

The Contractor shall submit the shop drawings together with the load calculations for jack capacity of jack up girder shall be approved by the Engineer. considering dead load and live load during the replacement work.

(2) Casting New Bearing Seat and Set up New Bearings

The Contractor shall submit shop drawings stating the materials to be used and specifications for the new bearing seat to be approved by the Engineer, prior to execution of related works.. After providing temporary support for the girders near the bearing locations, old bearings shall be removed. Position and level for the new bearings shall be set-up in accordance with approved plans and specifications.

(3) 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.

(4) Dismantle Jacks and Temporary Supports as Final Work

When the reaction is safely transferred from the jack to the new bearing, jacking device shall be dismantled.

Temporary support materials as well shall also be dismantled safely.

9-1-6 Measurement and Payment

9-1-6-1 Method of Measurement

The method of measurement for replacement of bearings shall be by number quantity approved by the Engineer.

9-1-6-2 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..

9-2 EXTENSION OF BEARING SEAT

9-2-1 Description of Repair Method

Normally, the bearings transmit all the loads (dead load, live load, wind pressure, and others) from the superstructure to the substructure. Consequently, reaction is concentrated near the bearing seat. This sometimes causes damage to the bearing seat. If such defects are found, damaged concrete shall be removed completely. Anchor bars shall be connected to the existing bearing seat to extend the seat width accordingly. Non-shrink concrete shall finally be poured to the extended bearing seat.

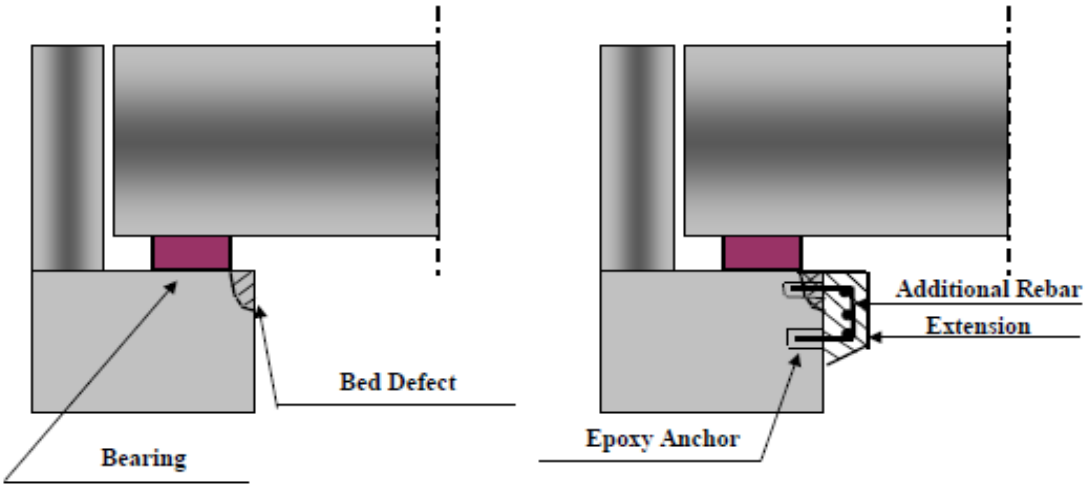


Figure 9-2 Concept of Extension Bearing Seat

9-2-2 Application Criteria

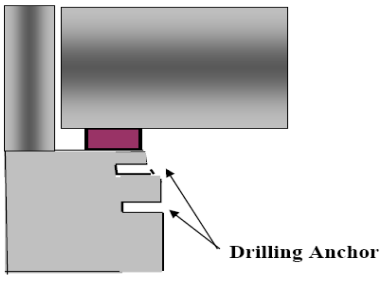
Bearings are sometimes installed close to the edge of the concrete coping. There are cases that these coping edges break off due to support reactions from traffic impact loading. This signifies risk of superstructure collapse as the required bearing seat was reduced. Hence, this repair method is intended to eliminate said risk by extending further the existing bearing seat.

9-2-3 Work Sequence

(1) Chipping and Drilling Holes

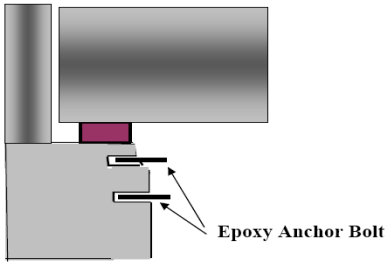
The spalled or delaminated potion shall be removed completely by hammer chipping or electric drilling. Holes for anchor bar shall be by drilled using electric drill device.

Drilling of holes shall be performed carefully in order to avoid damaging existing coping reinforcements.



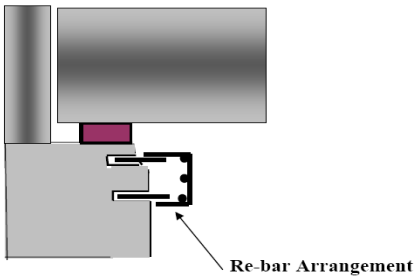
(2) Anchor Bar Fitting

Drilled hole shall be filled with epoxy adhesive before completely placing required anchor bars.



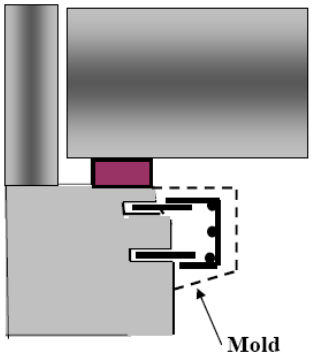
(3) Arrangement of re-bars

After anchor bars are bonds with the drilled holes, new rebar , connected to the anchor bars, are arranged for the proposed extension of bearing seat.



(4) Formwork

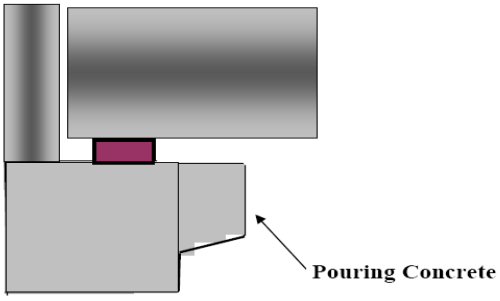
Formwork and required temporary supports are fixed immediately after application of bonding coats to concrete substrate and reinforcement.



(5) Pouring concrete

Concrete is then poured to the formed section. After concrete is completely in place, finishing and curing is performed. The rendered surface should match that of the existing structure.

Formworks shall be finally dismantled.



9-2-4 Required Materials and Tools/Equipment

9-2-4-1 Required Materials

- Primer to Concrete Surface (Epoxy adhesive),
- Anchor bar / Re-bar and concrete

9-2-4-2 Required Tools/Equipment

- Electric drill,
- Electric concrete vibrator
- Trowel

9-2-5 Specification

9-2-5-1 Material Requirement

Material specifications for this work item shall be similar to requirements presented in Section 6-3 of this manual Recasting. Material requirements shall applicable to the following items:

- Epoxy adhesive

- Anchor bar/Re-bar (refer to Item 710- Reinforcing Steel And Wire Rope, DPWH Standard Specifications).
- Concrete shall conform to the requirements of the specifications shown in Table 4-6

9-2-5-2 Construction Requirement

(1) Chipping and Drilling Concrete

The defective concrete should be removed completely by chipping. The Contractor should submit for Engineer's approval, shop drawings for the proposed extension of the bearing seat. The extent of concreting works shall be determined with the Engineer.

(2) Epoxy Adhesive and Anchor Bars

Epoxy adhesives shall be filled into the drilled hole. Anchor bars shall be inserted to the drilled hole filled with the adhesive. Sufficient curing time for the epoxy adhesive shall be instructed by the supplier.

(3) Arrangement of Re-bar

After curing anchor bar, re-bar for the extension of bearing seat shall be placed based on the approved shop drawings.

(4) Formworks

The contractor shall be install formworks/temporary supports required for casting the extended bearing seat, after inspection of rebar arrangement is conducted.

(5) Pouring Concrete

The Contractor shall submit material test results of non-shrink concrete for Engineer's approval. If test results are acceptable, the Contractor shall proceed with the concrete pouring of the bearing seat. The surface of non-shrink concrete shall be finished by trowel and cured with approved wet covering material.

9-2-6 Measurement and Payment

9-2-6-1 Method of Measurement

Repair works performed in accordance with the plans and this specification will be measured in cubic meters as verified with the Engineer.

9-2-6-2 Basis of Payment

The price and payment per cubic meter of extended bearing seat shall include full compensation for removal of deteriorated concrete, surface cleaning and preparation, furnishing and placing all materials, labor, equipment and tools as well as construction and removal of formworks and other temporary works necessary to complete this works.

9-3 JACK-UP GIRDER

9-3-1 Description of Repair Method

Jack up girder method is applied for replacement of bearings and re-arrangement of existing bearing. The computation of jack-up reaction shall be the responsibility of the designated Structural Engineer. Once the required quantity and capacity of hydraulic jacks are determined, this repair method shall then progress. Required scaffoldings shall also be provided. Jack-up device and temporary supports and jack base bracket shall be fabricated and installed below the concrete or steel girder near bearing locations. For steel girders, jack stiffener shall be welded in proper position before proceeding with raising the girder. During jacking operations, traffic may remain open but with under restricted speed and flow to maintain safety. The operation shall be simultaneously performed for all the girders. The height to be raised on a cyclic motion shall be limited to less than 5 mm in order to ensure constant reactions are transmitted from all the girders. The jack up procedure shall be repeated until the existing bearings are accessible for dismantling. The ideal jack up height could reach between 10 mm to 20 mm.

Photo 9-2 Sample of Replacement Bearing by Jack-up Girder

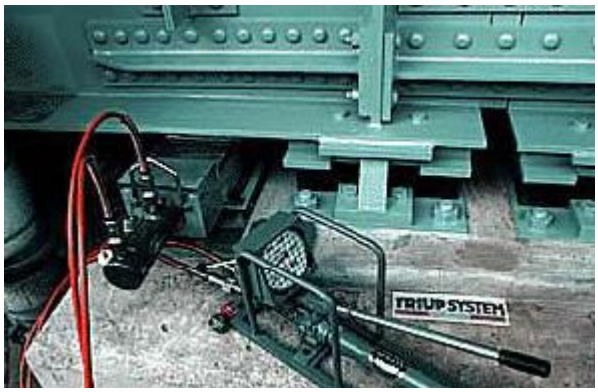


Photo 9-3 Hydraulic jack

Photo 9-4 50-ton hydraulic jack

9-3-2 Application Criteria

In case loose connection of steel bearings or bulging/cracking of rubber bearings are judged to as "Bad" as per suggested Condition Rating Criteria, jack-up method will be initiated to perform necessary repairs or replacement of bearings.

In case abnormal displacement of steel and rubber bearing are judged as "Bad", the jack-up method is also utilized for lifting the girder to reposition the bearing locations.

9-3-3 Work Sequence

9-3-3-1 Sequence of Jack-up method

The procedure of Jack-up method for replacement of bearings is presented in flowchart below:

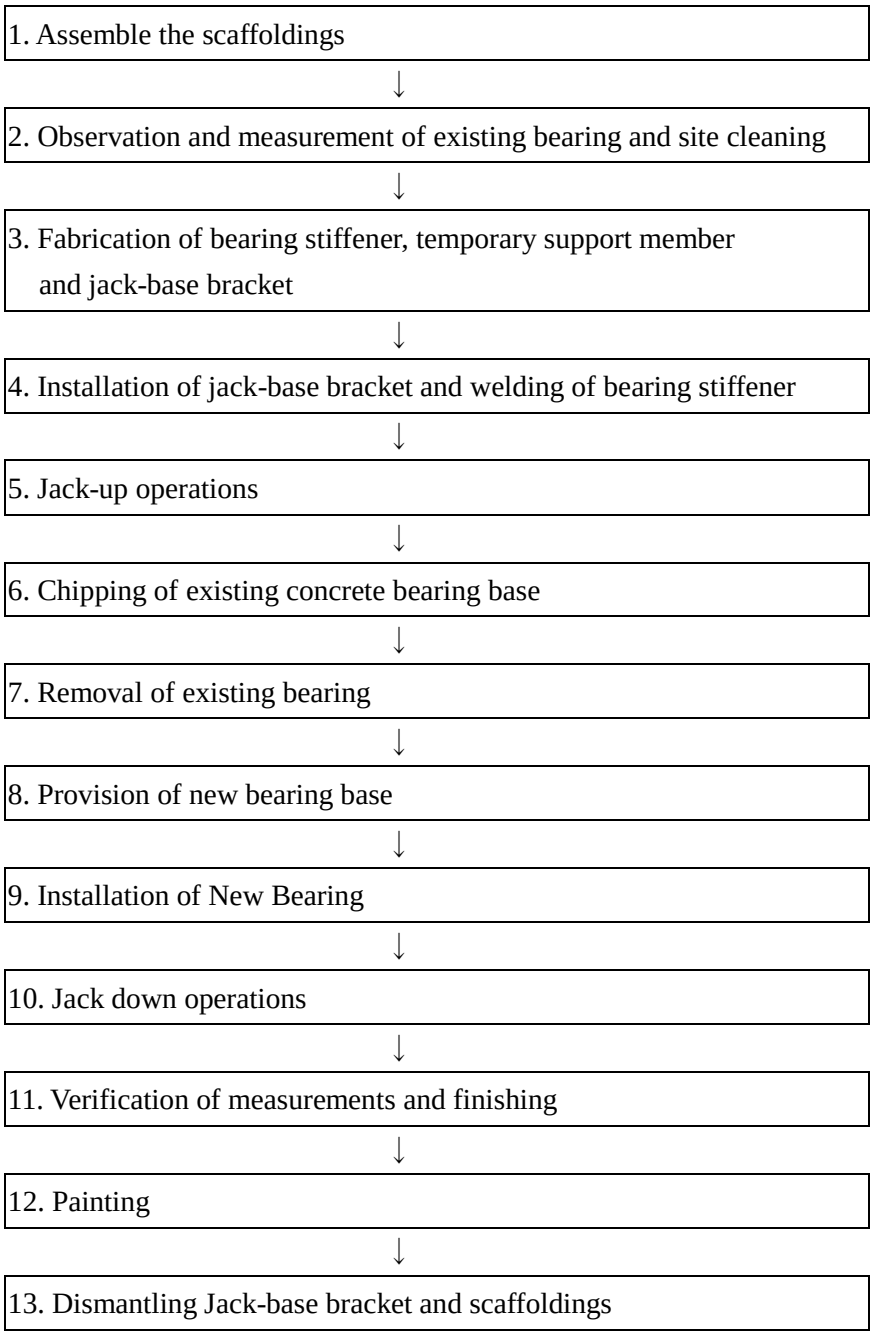
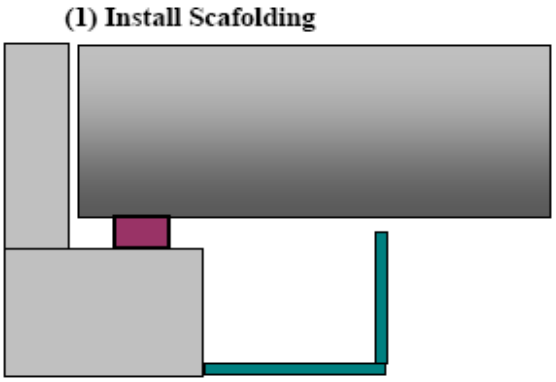


Figure 9-3 Flowchart of Jack-up Method for Replacement of Bearing

9-3-3-2 For Concrete Girder

(1) Preparation of materials, equipment and site cleaning

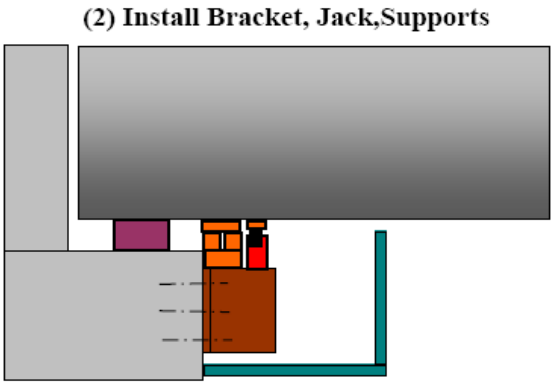
The Scaffolding is installed to prepare jack-up method to proceed. The jack base bracket shall be fabricated in the factory which is approved by the Engineer.



(2) Installation of Jack base frame

The Jack-base bracket is installed using epoxy anchor through drilled holes for anchor bolts.

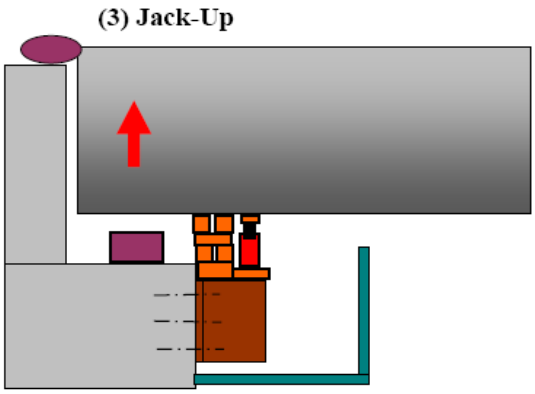
Hydraulic jack with capacity furnished by designated structural engineer is set up on the jack-base bracket. Temporary supporting member shall also be provided.



(3) Jacking up

Jack-up operations shall be simultaneously carried out for all the girders. For this condition, jacking up height is limited to 5 mm for each jack-up motion.

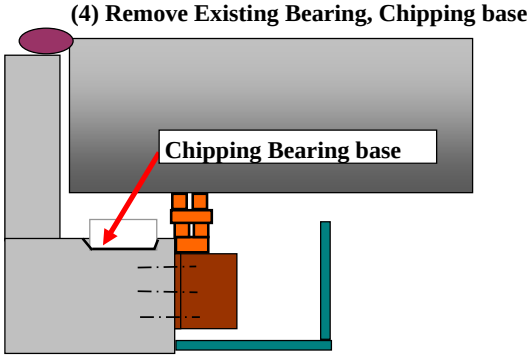
The method is repeated in gradually until enough jacking up height is achieved to allow for dismantling of the existing bearing.



(4) Chipping bearing base and remove existing Bearing

Concrete bearing base is chipped off to dismantle the existing bearings.

A slope between bridge approach and the expansion joint shall be maintained for passing traffic during jacking-up operations.

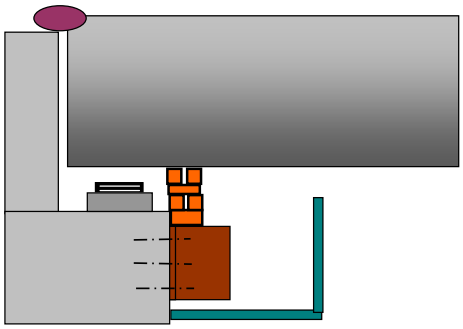


(5) Making new bearing base

Additional re-bars for the new bearing base shall be arranged.

After concrete is completely placed, new rubber bearings are installed on the bearing base. During this operation, the girder shall be temporarily supported. The measurement of height, location shall be carefully verified by a designated inspector.

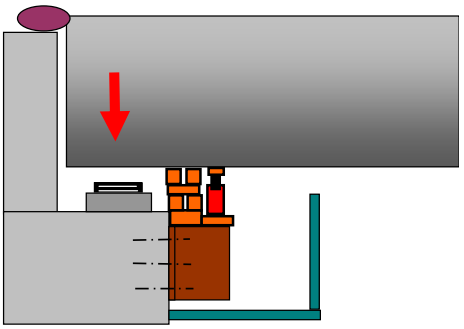
(5) Making New Bearing base, Set up New Bearing



(6) Jack down

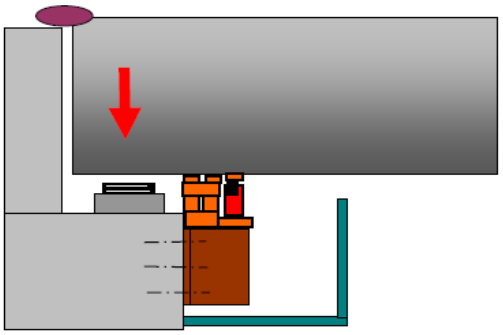
If the new bearing installed is determined satisfactory, jack down operations shall commence. It is important to maintain safety during this operation. Jacking down shall be carried out gradually while carefully removing the temporary supporting members.

(6-1) Jack down process, dismantle support in cyclic process



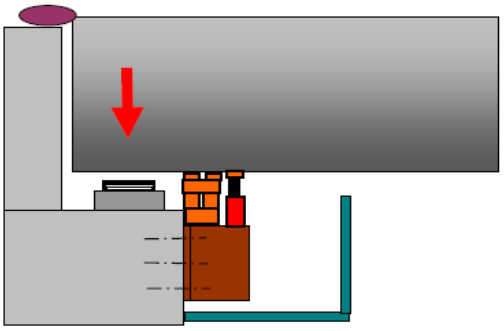
If the temporary support touches the lower surface of the girder during jack down operations, the jack base plate shall be changed with a lesser thickness. Stroke shall be extended to jack down. These steps shall be repeated in cycle. For safety purposes, each stroke should maintain a height of less than 5 mm.

(6-2) Jack down



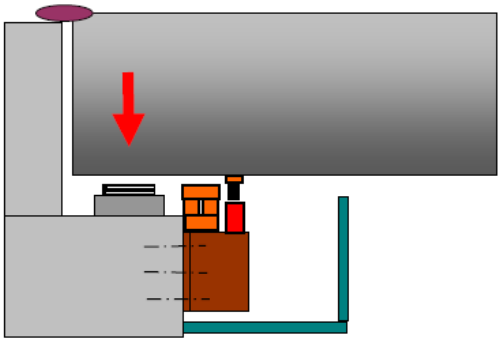
If the temporary support keeps touching the concrete surface, dismantle jack and remove jack base plate gradually.

(6-3) Dismantle jack



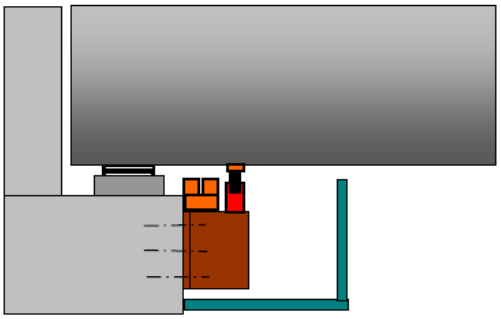
The temporary support shall be taken off from the concrete surface by jacking up slightly. The temporary support shall be dismantled gradually for every 5 mm jack down movement.

(6-4) Dismantle Support



Once the concrete girder finally rests completely on the bearings during jacking down motion, the exact location between the girder and bearing shall be measured immediately. If dimensions are acceptable, the jack can be dismantled completely.

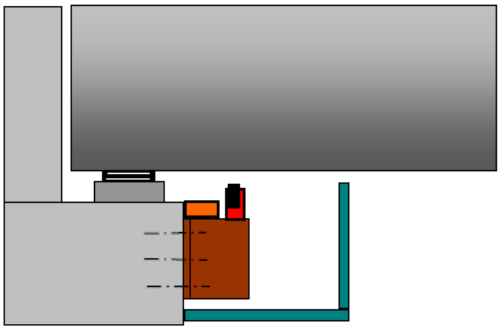
(6-5) Jack down



(7) Verification of measurement

Verification measurement shall be conducted to ensure final height, and exact location of all bearing positions. If not satisfactory, re-jack operations shall be repeated to perform adjustments.

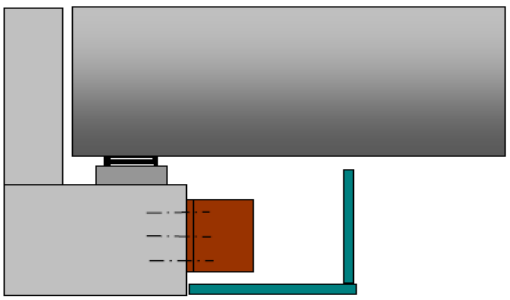
(7) Setting Inspection



(8) Dismantle Jacks and temporary supports

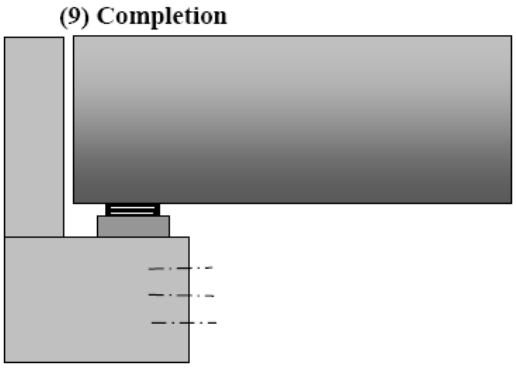
Jacks and temporary support materials shall be dismantled.

(8) Dismantle Jack and Support



(9) Completion

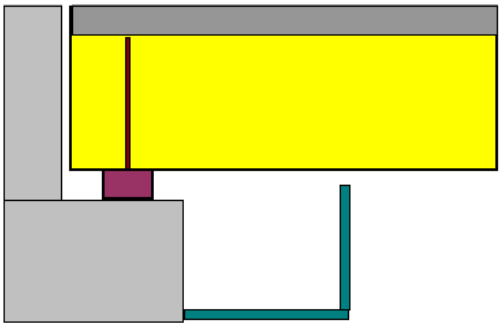
Clean-up site and ensure the measurements are approved by the Engineer.



9-3-3-3 For Steel Girder

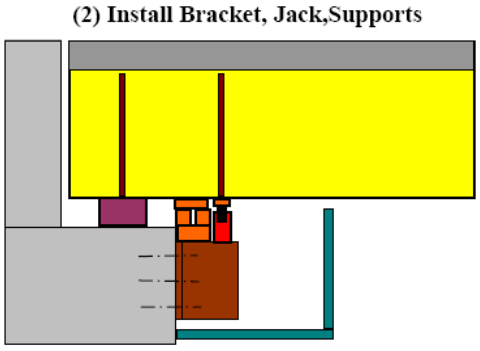
(1) Preparation of materials, equipment and site cleaning

The Scaffolding is installed to prepare jack-up method to proceed. The jack base bracket shall be fabricated in the factory which is approved by the Engineer.



(2) Welding temporary jack stiffeners

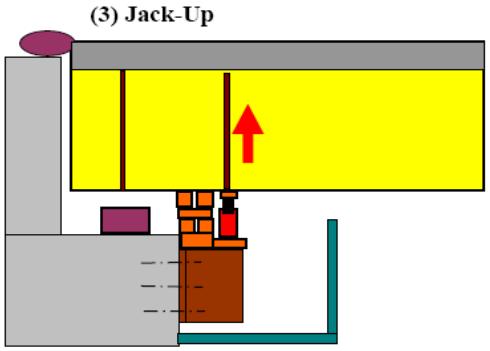
Jack stiffeners shall be welded to both sides of web plate. Jack-base bracket is installed using epoxy anchor installed at drilled holes for anchor bolts.



(3) Jacking up

Jack-up operations shall be simultaneously carried out for all the girders. For this condition, jacking up height is limited to 5 mm for each jack-up motion.

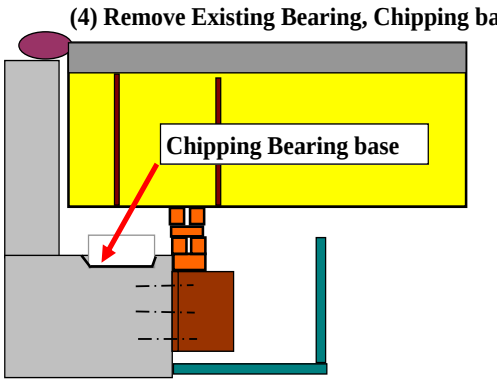
The method is repeated in gradually until enough jacking up height is achieved to allow for dismantling of the existing bearing.



(4) Chip-off bearing base and remove existing bearing

Concrete bearing base is chipped off to dismantle the existing bearings.

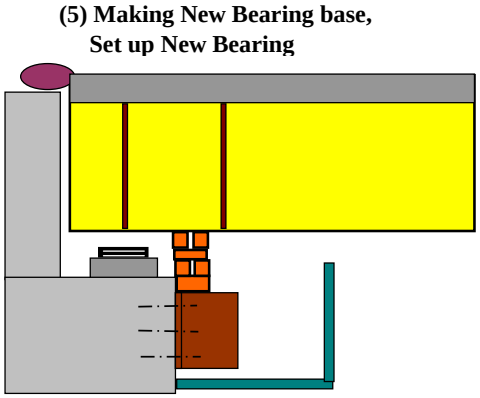
A slope between bridge approach and the expansion joint shall be maintained for passing traffic during jacking-up operations.



(5) Making new Bearing base

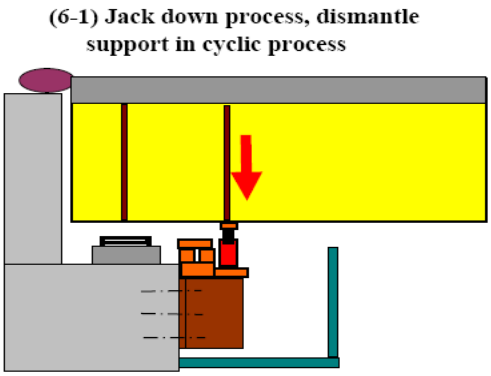
Additional re-bars for the new bearing base shall be arranged.

After concrete is completely placed, new rubber bearings are installed on the bearing base. During this operation, the girder shall be temporarily supported. The measurement of height, location shall be carefully verified by a designated inspector.

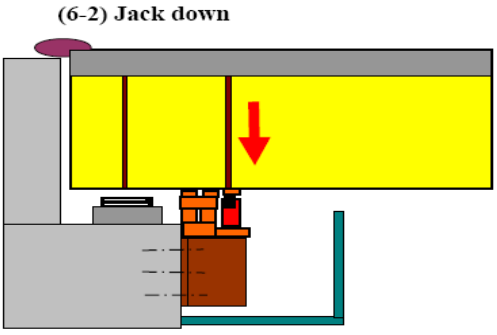


(6) Jack down

If the new bearing installed is determined satisfactorily, jack down operations shall commence. It is important to maintain safety during this operation. Jacking down shall be carried out gradually while carefully removing the temporary supporting members.

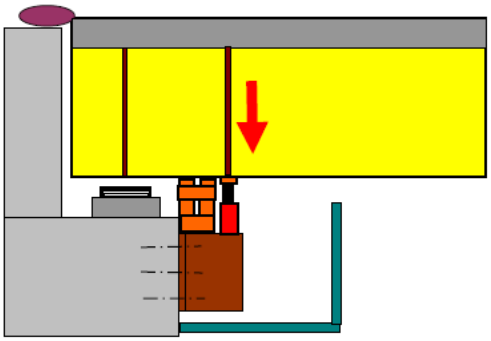


If the temporary support touches the lower surface of the bottom flange during jack down operations, the jack base plate shall be changed with a lesser thickness. Stroke shall be extended to jack down. These steps shall be repeated in cycle. For safety purposes, each stroke should maintain a height of less than 5 mm.



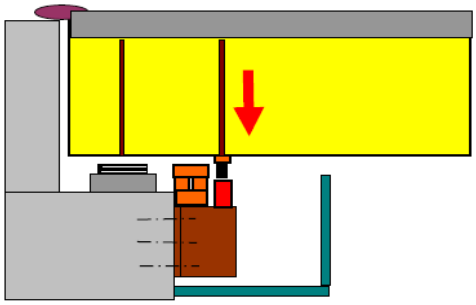
If the temporary support keeps touching the lower flange, dismantle jack and remove jack base plate gradually.

(6-3) Dismantle jack



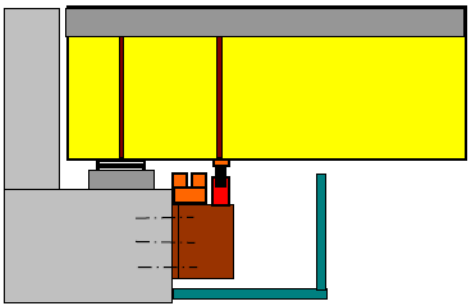
The temporary support shall be taken off from the steel girder by jacking up slightly. The temporary support shall be dismantled gradually for every 5 mm jack down movement.

(6-4) Dismantle Support



Once the lower flange finally rests completely on the bearings during jacking down motion, the exact location between the girder and bearing shall be measured immediately. If dimensions are acceptable, the jack can be dismantled completely.

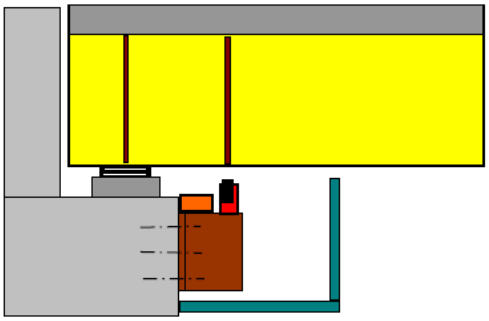
(6-5) Jack down



(7) Inspection of measurement

Verification measurement shall be conducted to ensure final height, and exact location of all bearing positions. If not satisfactory, re-jack operations shall be repeated to perform adjustments.

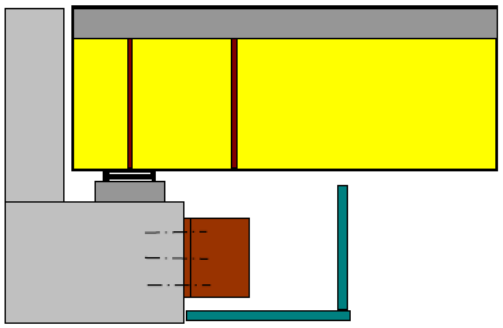
(7) Setting Inspection



(8) Dismantle Jacks and temporary supports

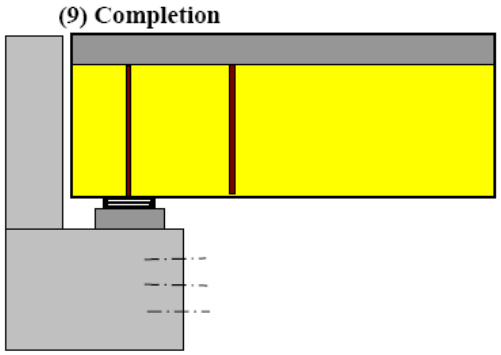
Jacks, temporary support materials shall be dismantled. Paint steel portion, if found necessary. Dismantle any installed scaffoldings.

(8) Dismantle Jack and Support



(9) Completion

Cleanup site and ensure the measurements are approved by the Engineer.



9-3-4 Required Materials and Tools/Equipment

9-3-4-1 Required Materials

- New bearings, (if the purpose is Replacement of Bearing)
- Epoxy anchor bolt for jack base bracket
- Temporary support material for jacking up motion
- Paint (if required)

9-3-4-2 Required Tools/Equipment

- Hydraulic Jack
- Welding machine
- Hammer
- Electric jackhammer for chipping
- Concrete drilling machine

9-3-5 Specification

9-3-5-1 Material Requirement

Epoxy resin for anchor bar shall be as per Table 4-1 given in previous sections.

Aluminum paint shall be referred to Item 709 (PAINTS) of the DPWH Standard Specifications

Steel material for stiffener and welding shall be referred to Item 712 – (STRUCTURAL METAL) of the DPWH Standard Specifications.

Re-bar for anchor shall be referred to Item 710 (REINFORCING STEEL AND WIRE ROPE) DPWH Standard Specifications

Concrete for bearing base shall be referred to Item 405 (STRUCTURAL CONCRETE) of the DPWH Standard Specifications

9-3-5-2 Construction Requirement

(1) Preparation of materials, equipment and site cleaning

The contractor shall submit for Engineer's approval, shop drawing for the work required. Jacking capacity, epoxy anchor size its required quantities shall be as per Engineer's advice.

(2) Installation of Jack base frame

Epoxy anchor bolt hole shall be installed on the vertical face of pier/abutment using electric drill device. Epoxy adhesive shall be filled inside the holes and anchor bolts set up then cured in proper time. If curing period of epoxy anchor is completed, the jack base frame shall be installed. The Contractor shall submit tensile test of epoxy anchor for Engineer's approval.

(3) Jacking up

The Contractor shall submit jack devices guarantee certificate of performance and service data for approval of the Engineer. The jack accessories shall be verified and confirmed by its supplier prior to installation for the girder, to ensure no oil leaks. The limit of relative height difference below 5mm during jacking up motion shall be maintained for quality control.

(4) Chipping bearing base and dismantle existing bearing

After jack up is completed, existing bearings shall be dismantled/re-positioned. If bearings need to be replaced, chipping off of concrete shall be initiated. Girders shall be supported with temporary support member until the jack down operations.

(5) Making new Bearing base

Chipping off bearing base shall be initiated using electric jack hammer. Additional rebars for the new bearing base shall be placed. The contractor shall submit measurement verifications of actual rebar arrangement for Engineer's approval. If arrangement is satisfactory, concrete shall be poured to the new bearing base. Concrete shall then be allowed to cure properly. The Contractor shall submit test results of concrete compressive strength to the Engineer for his approval. The new rubber bearings shall be installed at proper locations on the bearing base.

(6) Jacking down

After approval of inspection, the contractor shall jack down the girder carefully. It should be noted that jack down motion is dangerous than jack up motion. The Contractor should therefore strictly maintain the gradual jack down motion to 5mm for safety purposes.

(7) Verification Measurement

During jack down motion, the reaction shall be consequently transferred to the new bearing from the temporary support member. The Contractor shall submit the result of verification measurement for Engineer's approval.

(8) Dismantle jack and temporary support

The jack, temporary support and scaffoldings shall be dismantled immediately.

(9) Completion

Clean-up site and ensure that final measurements are acceptable and approved by the Engineer.

9-3-6 Measurement and Payment

9-3-6-1 Method of Measurement

The quantity for this work item shall be the actual quantity placed and accepted during the progress of the work. The temporary support material shall be included in quantity.

9-3-6-2 Basis of Payment

The accepted quantities, measured as prescribed in Section 9-3-6-1 shall be paid for at a contract unit price for each of the approved pay item included in the bill of quantities.

9-4 REPAINT OF STEEL BEARING

9-4-1 Description of Repair Method

Steel bearings are provided at bridge abutments and piers. Typically, due to the deterioration of water proofing at expansion joints over the years, steel bearings underneath the superstructure are subjected to corrosion.

Bearings serve as interface between girder and substructure. The gap between girder's bottom surface and top level of bearing seat is usually narrow, making it difficult to perform repainting of bearings. Nevertheless, it is necessary to ensure that condition is dry and satisfactory before carrying out any surface preparation. Repainting of bearings shall proceed after surface preparation, in accordance with Section 7-1 (Repainting) of this manual. If 1st grade surface preparation is required, epoxy zinc rich primer and polyurethane aluminum paint shall be applied. Meanwhile, epoxy polymide primer and polyurethane aluminum paint shall be applied for 2nd grade surface preparation. Finally, if 3rd grade surface preparation is necessary, special anti-corrosion paint shall be provided.

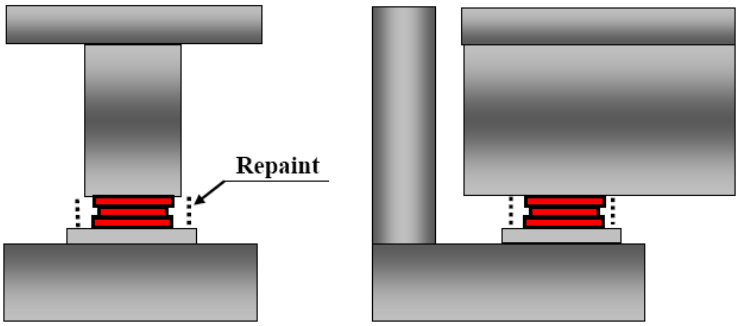


Figure 9-4 Repaint of Steel Bearing

9-4-2 Application Criteria

Steel bearings shall be subject to repainting if based on results of bridge inspection, a "bad" rating is given due to observed severe corrosion or section loss of more than 20%.

9-4-3 Work Sequence

This repair method is basically similar to requirements in Section 7-1 and 7-5 of this manual, for Repainting and Special Anti –Corrosion Paint, respectively.

(1) Scaffolding

Repainting of bearings on abutments will not require scaffolding. On piers however, scaffoldings need to be installed to access the bearings, and for safety purposes.

(2) Surface Preparation for Steel Bearings

Surface preparation for steel bearings is requisite to repainting required. The surface preparation classification shall be as per Table 2-3-2 (Touch-up Painting).

The 1st Grade preparation is intended for severely corroded steel surface, where sand blast machine is utilized to achieve near white blast surface.

The 2nd Grade preparation is for fairly to badly corroded steel surface where electric disc grinder will be necessary to remove the remaining coating film.

Lastly, 3rd Grade preparation is applied to surfaces where sound coating film still remains. Cleaning is for this preparation requires wire brush, scraper and electric disc grinder.

During removal of coating film, it is important to ensure that the works do not have impacts to the environment as it could scatter dust, dirt and scale that may contain lead and other harmful elements.

(3) Painting

Painting is mainly applied with the use of paint brush and paint roller. These tools are environment friendly and save costs. Quality control of painting should be strictly executed to maintain required coating film thickness. Measurement of coating film thickness after it dries can be easily done using thickness meter gauge.

9-4-4 Required Materials and Tools/Equipment

9-4-4-1 Required Materials

- Zinc-rich base primer
- Polyurethane Aluminum Paint – Aluminum paint shall consist of aluminum bronze powder or paste of the required fineness and composition to which shall be added the specified amount of agent component.
- Thinner
- Modified epoxy polymide primer
- Special Anti-Corrosion paint

DPWH Standard Specification ITEM 709-Paint also applies to this work item.

9-4-4-2 Required Tools/Equipment

- Water jet spray, water tank, water hose, brush and generator for washing Bearing.
- Wire brush, scraper, electric disc grinder, sand blast machine, air compressor and generator for surface preparation
- Paint brush and paint roller

9-4-5 Specification

9-4-5-1 Material Requirements

Repainting shall be applied according to three grades of surface preparation as follows:

Table 9-1 Specification for 1st Grade Surface Preparation

Function	Description	DFT(μ)	Test Method	Painting Interval
Surface Preparation	Near white Blast Cleaning to remove paint, rust, scale, dirt, grease or other foreign matters. Solvent cleaning by lacquer thinner to remove dirt, oil, grease and other contaminants. All surfaces to be painted must be dry and free from dust. (SSPC-SP10)			4 hrs
1st Coat: Primer	Epoxy Zinc Rich Primer (SSPC-Paint No.20)	75	ASTM D520	8 hrs
2nd Coat : Top Coat (For Lower Flange Plate)	Epoxy Zinc Rich Primer (SSPC-Paint No.20)	75	ASTM D520	8 hrs
3rd Coat: Intermediate Coat	Polyurethane Aluminum Paint （SSPC-Paint No.36）	50	ASTM D16,Type V polyurethane	4 hrs
4th Coat: Top Coat	Polyurethane Aluminum Paint （SSPC-Paint No.36）	50	ASTM D16,Type V polyurethane	4 hrs

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

Table 9-2 Specification for 2nd Grade Surface Preparation

Function	Description	DFT(μ)	Test Method	Painting Interval
Surface Preparation	Power Tool Cleaning to remove existing paint, rust, scale, stains and other foreign matters. Solvent cleaning by lacquer thinner to remove dirt, oil, grease and other contaminants. All surfaces to be painted must be dry and free from dust.(SSPC-SP10)			4 hrs
1st Coat: Primer	Modified Epoxy Polyimide Paint (SSPC-PS13.01)	75	ASTM D1652	8 hrs
2nd Coat : Top Coat (For Lower Flange Plate)	Modified Epoxy Polyimide Paint (SSPC-PS13.01)	75	ASTM D1652	8 hrs
3rd Coat: Intermediate Coat	Polyurethane Aluminum Paint （SSPC-Paint No.36）	50	ASTM D16,Type V polyurethane	4 hrs
4th Coat: Top Coat	Polyurethane Aluminum Paint （SSPC-Paint No.36）	50	ASTM D16,Type V polyurethane	4 hrs

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

Table 9-3 Specification for 3rd Grade Surface Preparation

Physical and material test and Specification is mentioned in below table.

Function	Description	DFT(μ)	Test Method	Painting Interval
Surface Preparation	Hand tool and power tool cleaning device to remove existing paint, rust, scale, stains and other foreign matters; Solvent cleaning with lacquer thinner required to remove dirt, oil, grease and other contaminants; All surfaces to be painted must be dry and free from dust.			4 hrs
1st Coat:	Special Anti-Corrosion Paint	250	JIS A6909 / ASTM D7234	2 hrs
2nd Coat: Top Coat	Special Anti-Corrosion Paint	250	JIS A6909 / ASTM D7234	2 hrs

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

Appropriate material should be selected in accordance with manufacturer's instructions.

9-4-5-2 Construction Requirement

(1) Surface Preparation

The Contractor shall clean up the site and assess the defects due to corrosion on bearings. The Contractor shall then submit a plan drawing related to proposed painting to the bearings, subject to approval of the Engineer. The Contractor, in close coordination with the Engineer, shall also propose the suitable grade of surface preparation and painting system.

(2) Painting

Painting for bearing shall be done using hand paint brush. After surface preparation, the primer or 1st layer coating shall be painted immediately, within 4 hours. Intermediate layer and top coat paint shall be applied as well using hand paint brush. After paint coating has dried, total thickness of coating film shall be measured using an electric thickness gauge.

9-4-6 Measurement and Payment

9-4-6-1 Method of Measurement

The method of measurement for repainting of bearings shall be by the total square meters of steel surfaces area, determined with the Engineer.

9-4-6-2 Basis of Payment

Repainting works will be paid for at a unit price per square meter as item for "Repainting Steel Bearings", complete in place, which shall include all materials, containers, equipment, tools, labor, service advisor and work incidentals for the works. Any indirect cost item shall not be paid separately. This shall be deemed included in the square meter price.

CHAPTER 10 PROTECTION WORKS

10-1 SLOPE PROTECTION WITH FOUNDATION SUPPORTED BY PILES

10-1-1 Description of Repair Method

Slope protection around the abutment is often damaged due to scouring, rapid river flow, or improper construction, as shown in Photo 10-1. In most of the defective cases observed, foundation for the slope protection was not provided; hence, the protection eventually fails due to either sliding or scouring. Repair method for the slope protection involves provision of appropriate foundation at its base.

Photo 10-1 Broken Slope Protection

10-1-2 Application Criteria

Appropriate type will be selected from among slope protection works such as stone masonry, grouted riprap and concrete masonry. The foundation should be a concrete base with wooden pile as shown in Figure 10-1. The wooden pile is normally driven to a minimum depth of 2.0 m. The foundation is usually placed at 1.0 m level below the river bed.

This criterion is only applicable as a standard repair method to damaged protection near small and medium rivers.

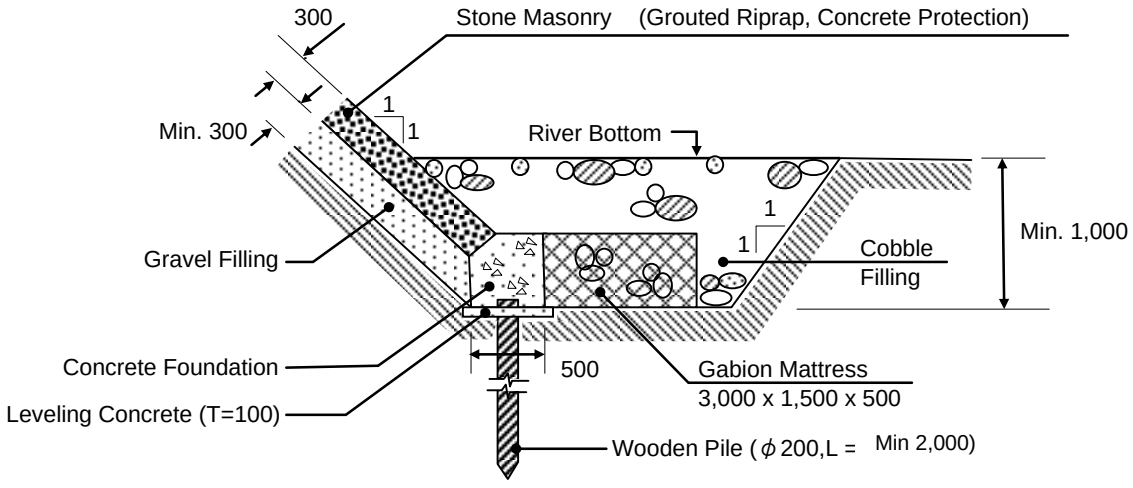
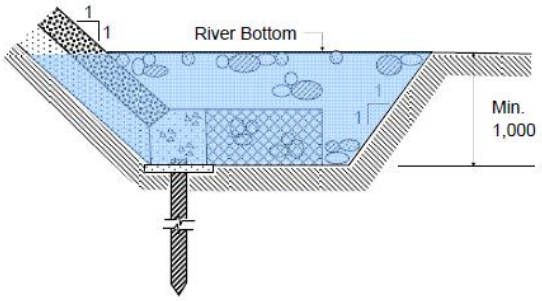


Figure 10-1 Foundation on Pile for Slope Protection Works

10-1-3 Work Sequence

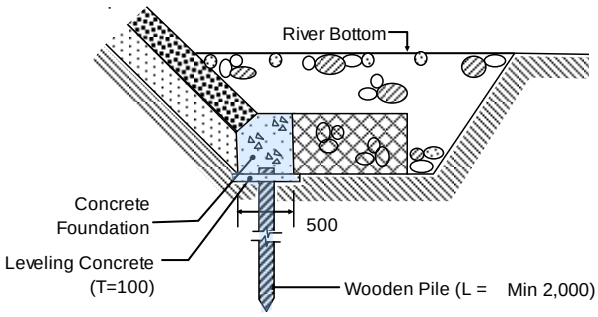
(1) Excavation of Scoured Area

The damaged section of the existing slope protection shall be demolished, and the scoured section excavated in accordance with the alignment and depth shown on the drawings. The limit of demolition is marked on the existing protection. After excavation, the bed surface is compacted using lightweight mechanical or vibratory compactor.



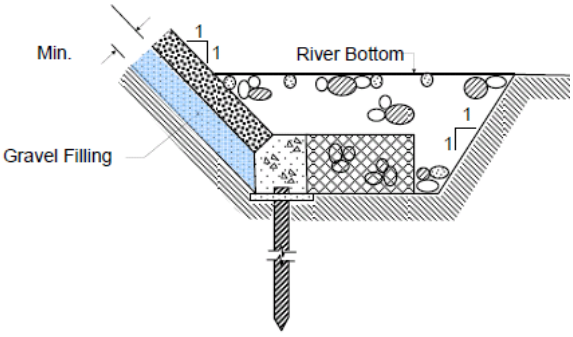
(2) Placing Concrete Foundation

Wooden piles are driven at an interval of 1.5 m. When driven depth is achieved, excess protruding length is cut. Concrete foundation, provided with minimum reinforcements, is formed and casted above the piles. If river water exists, sand bags acting as cofferdam is provided during foundation works.



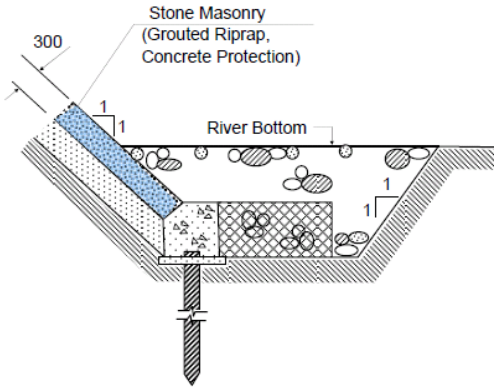
(3) Compaction of Gravel Filling

Natural slope surface shall be properly compacted. Gravel filling for the masonry base is then placed and compacted using lightweight mechanical or vibratory compactor. A thickness of more than 300 mm, placed in 2 layers, is provided at the slope base.



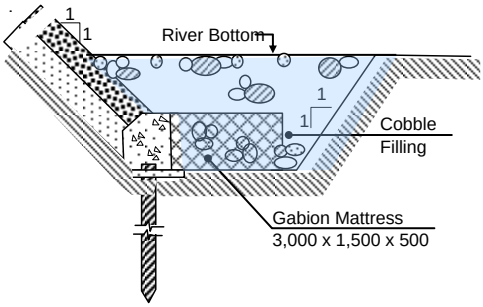
(4) Placing Masonry

Appropriate masonry type will be selected from among variety of slope protection works such as stone masonry, grouted riprap and concrete masonry.



(5) Installation of Gabion Mattress and Backfill

After filter fabric sheet is spread tightly on the bed, gabion mattress is installed in front of the concrete foundation as protection against local scouring and sliding. Finally, the excavated area and voids around the protection structure are backfilled with cobble stones, up to the level of river bed.



10-1-4 Required Materials and Tools/Equipment

10-1-4-1 Required Materials

- Gabion Mattress
- Rock Fill
- Wooden Pile
- Concrete with minimum steel reinforcements
- Filter Fabric Sheet (under gabion mattress)
- Backfill Materials
- Sand bag as cofferdam, when necessary

10-1-4-2 Required Equipment

- Vibratory compactor
- Backhoe

10-1-5 Specifications

10-1-5-1 Material Requirement

All materials required for the gabion mattress are in accordance with DPWH Standard Specifications contained in Item 505-Grouted Riprap, Item 506-Stone Masonry and Item-510-Concrete Slope protection.

10-1-5-2 Construction Requirement

Construction requirements for the slope protection are in accordance with relevant provisions in the DPWH Standard Specifications contained in Item 505-Grouted Riprap, Item 506-Stone Masonry and Item-510-Concrete Slope protection.

10-1-6 Measurement and Payment

10-1-6-1 Method of Measurement

The works shall be measured for in accordance with relevant provisions in the DPWH Standard Specifications contained in Item 505-Grouted Riprap, Item 506-Stone Masonry and Item-510-Concrete Slope protection.

10-1-6-2 Basis of Payment

The quantity measured as prescribed above, shall be paid in accordance with relevant provisions of the DPWH Standard Specifications contained in Item 505-Grouted Riprap, Item 506-Stone Masonry and Item-510-Concrete Slope protection.

10-2 GABION MATTRESS

10-2-1 Description of Repair Method

Local scouring around the pier often occurs due to strong stream flow, weak riverbed materials and type of foundation as shown in Photo 10-2. The worst damage that could occur due to scouring is the settlement of the bridge pier, eventually leading to undermining of the base and failure of the bridge. Thus, protection against local scouring is intended to eliminate or minimize future damage to the bridge substructure.

Photo 10-2 Local Scouring around Pier

10-2-2 Application Criteria

As a simple and effective repair method, gabion mattress is selected as protection for local scouring around bridge piers. The scoured area need to be excavated to a minimum 1.0 m depth for the gabion mattress installation. A filter fabric sheet should be laid under the mattress. From either edge of the pier shaft, the extending width of the upper mattress is ideally twice the estimated scour depth while three times for the lower mattress, as shown in Figure 10-2.

This criterion is only applicable as a standard repair method to damaged protection at small and medium rivers with a maximum discharge of 500 m^3/sec.

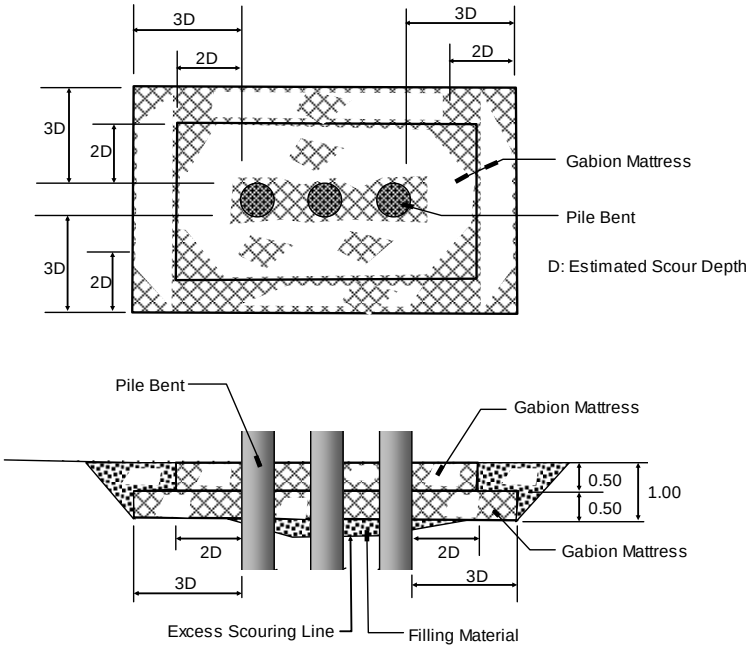
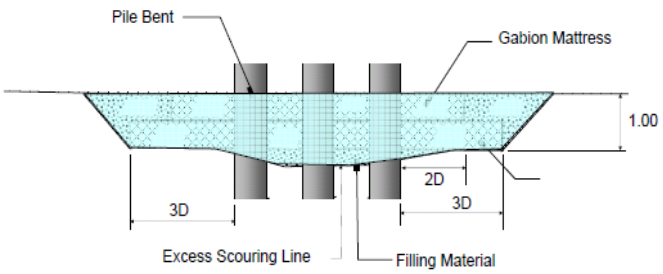


Figure 10-2 Application Requirement for Standard Gabion Mattress

10-2-3 Work Sequence

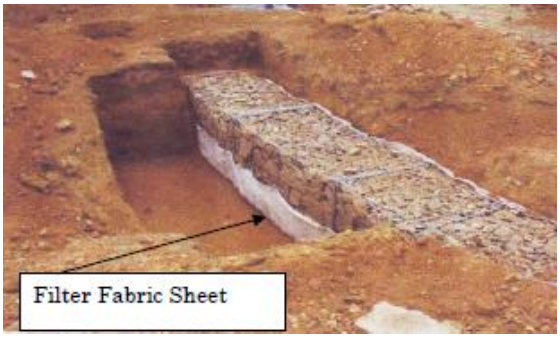
(1) Excavation of Scoured Area

The scoured area around pier base is excavated in accordance with the alignment and depth indicated in the drawings. The actual excess scour section below the depth shown in the drawings is filled with selected material. After excavation, the bed surface is compacted using vibratory compactor.



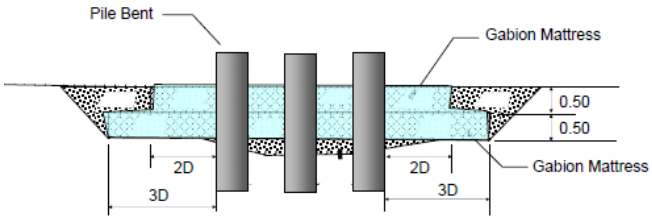
(2) Filter Fabric Sheet Placing

A filter fabric sheet shall be spread tightly and pegged with material approved by the Engineer. The filter fabric sheet shall be placed with a minimum 30 cm lapping.



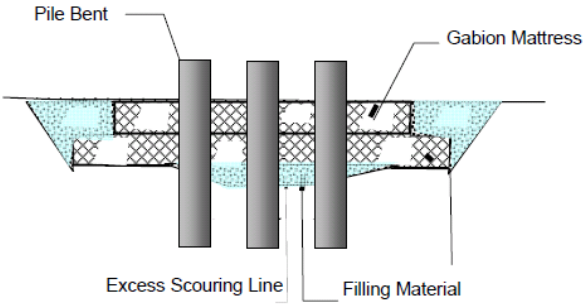
(3) Installation of Gabions

Gabion filling shall be carried out by placing individual stone material into the gabion. When the gabion mattresses are completely filled, the cover panels shall be closed and the edges tied with binding wire as in a typical assembly process. The formed mattress shall be completely tight and square.



(4) Backfilling

The backfill shall be placed evenly on all sides of the formed protection as appropriate. Each backfill layer shall extend to the limits of excavation or to natural ground.



10-2-4 Required Materials and Tools/Equipment

10-2-4-1 Required Materials

- Gabion Mattress
- Rock Fill
- Filter Fabric Sheet
- Backfill Materials

10-2-4-2 Required Equipment

- Vibratory compactor

10-2-5 Specification

10-2-5-1 Material Requirement

All materials required for the gabion mattress are in accordance with the DPWH Standard Specifications, Item 511-Gabions and Mattresses.

10-2-5-2 Construction Requirement

(1) Excavation and Backfilling

The base for the gabions shall be excavated to the required extent and level. The excess area around the finally formed gabion shall be backfilled in accordance with the relevant provisions of the DPWH Standard Specifications. Each layer of backfill shall be compacted using an approved vibratory compactor.

(2) Filter Fabric Sheet Placing

The level where the filter fabric sheet is to be placed shall be thoroughly cleaned of debris, wood or any other foreign materials. The filter fabric sheet shall be spread tightly and pegged with material approved by the Engineer. The filter fabric sheet shall be placed with a 30 cm overlapping.

(3) Installation of Gabion

Where mattress are being assembled in position in a revetment, the binding of the edges of each mattress in the assembly process, and the binding together of adjacent mattress may be carried out simultaneously. The vertical corners shall be kept square and to full dimension by inserting a steel bar of at least 20 mm diameter at each vertical corner, maintaining the correct final position throughout the filling process. Edges of the mattress panels shall be tied with binding wire. The placing of individual stone material into the gabion shall be done by hand. In this case, the stones shall be bear on each other, and packed similar to dry random rubble masonry. No loose stones shall be placed into the mattress. Packing the outer layer and filling its interior with unspecified stones shall not be permitted. When the mattresses are completely filled, the cover panels shall be closed and its edges are tied with binding wire as in the usual assembly process. The formed mattress shall be completely tight and square, and in accordance with the dimensions, alignment and level shown on drawings.

(4) Backfilling

Backfill for the gabion mattress shall be in accordance with DPWH Standard Specifications Item 103.2.6.

The backfill shall be appropriately filled up evenly on all sides of the mattress. Each layer shall extend to the limits of the excavation or to natural ground.

10-2-6 Measurement and Payment

10-2-6-1 Method of Measurement

The works for this repair works shall be measured is in accordance with DPWH Standard Specifications, Item 511-Gabions and Mattresses.

10-2-6-2 Basis of Payment

The quantity, measured as prescribed above, shall be paid in accordance with DPWH Standard Specifications, Item 511-Gabions and Mattresses.

10-3 SLOPE PATCHING

10-3-1 Description of Repair Method

Slope protection around the abutment is often damaged due to inadequate compaction of slope embankment, strong stream flow and insufficient flood drains. Although visible damage to the slope protection may be limited, voids may formed already under the protection due to the base failure. A large section of the slope protection, including the damaged portion, should be removed for purposes of patching repair.

Photo 10-3 Damaged Slope Protection

10-3-2 Application Criteria

Slope patching is an effective method that can be adopted to repair the limited damages on the masonry, during the early stage of visible defects. The area to be removed shall extend to a minimum of 500 mm around the perimeter of the damaged section. The protection bed should be excavated to a depth of 600 mm from masonry surface, as shown in Figure 10-3. New masonry patched into the excavated portion shall consist of 300 mm gravel filling and 300 mm masonry material as shown in Figure 10-4.

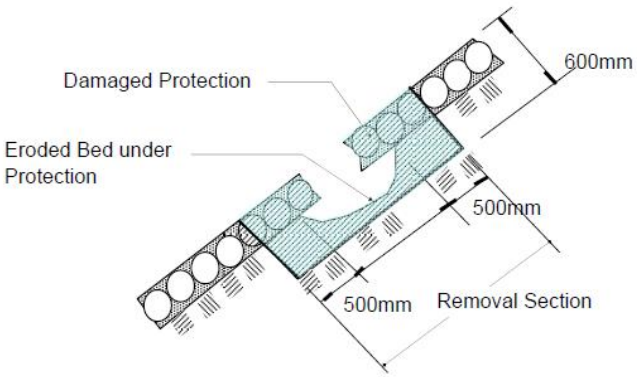


Figure 10-3 Typical Damaged Slope Protection

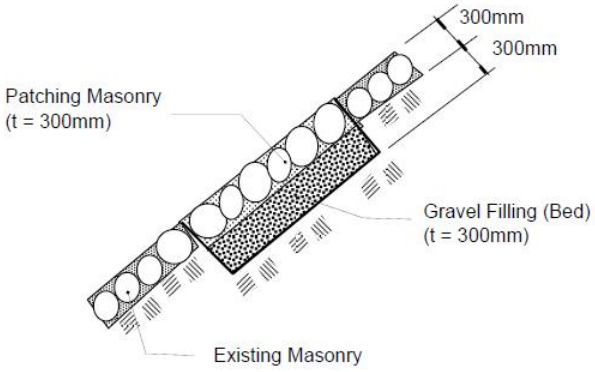
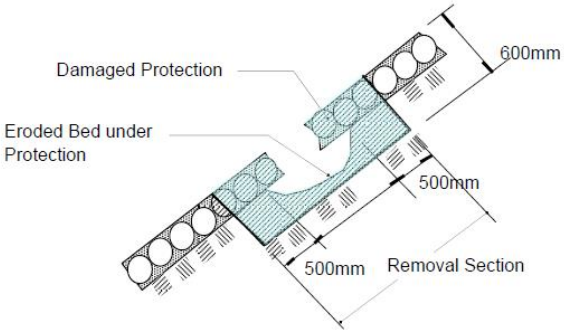


Figure 10-4 Slope Protection After Repair

10-3-3 Work Sequence

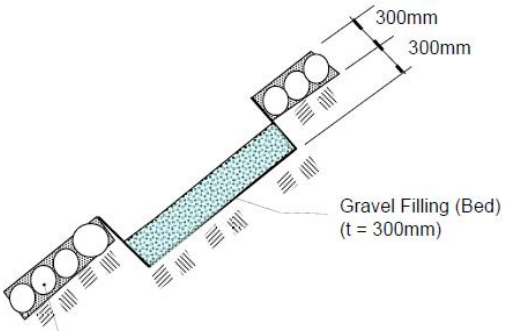
(1) Removal of Damaged Protection

The damaged section of the existing slope protection shall be removed, and the scoured section excavated in accordance with the alignment and depth shown on the drawings. The limit of removal is marked on the surface of existing protection. After excavation, the bed surface is compacted using vibratory compactor.



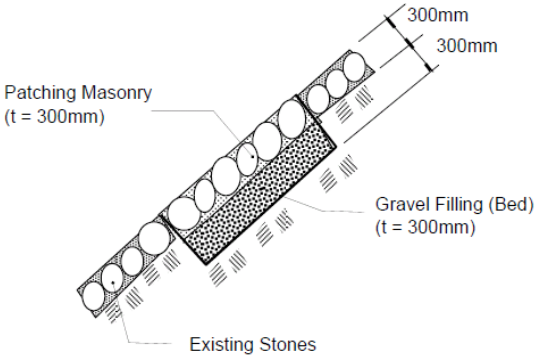
(2) Compaction of Gravel Filling

Natural slope surface shall be properly compacted. Gravel filling for the masonry base is then placed and compacted using vibratory compactor. A thickness of more than 300 mm, placed in 2 layers, is provided at the slope base.



(3) Patching Masonry

Appropriate masonry material will be selected depending on the type of existing masonry (stone masonry, grouted riprap and concrete masonry.)



10-3-4 Required Materials and Tools/Equipment

10-3-4-1 Required Materials

- Masonry materials (Refer to DPWH Standard Specifications)
- Crushed Stone

10-3-4-2 Required Equipment

- Vibratory compactor

10-3-5 Specification

10-3-5-1 Material Requirement

All materials required for the slope protection shall be in accordance with DPWH Standard Specifications, Item 505-Grouted Riprap, Item 506-Stone Masonry and Item-510-Concrete Slope protection.

10-3-5-2 Construction Requirement

Construction requirements for the slope protection shall be in accordance with DPWH Standard Specifications, Item 505-Grouted Riprap, Item 506-Stone Masonry and Item-510-Concrete Slope protection.

10-3-6 Measurement and Payment

10-3-6-1 Method of Measurement

The works shall be measured in accordance with DPWH Standard Specifications, Item 505-Grouted Riprap, Item 506-Stone Masonry and Item-510-Concrete Slope protection.

10-3-6-2 Basis of Payment

The quantity, measured as prescribed above, shall be paid in accordance with DPWH Standard Specification Item 505-Grouted Riprap, Item 506-Stone Masonry and Item-510-Concrete Slope protection.

10-4 NYLON FIBER GABION

10-4-1 Description of Repair Method

Due to strong river flow, local scouring surrounding bridge piers often occurs. The worst damage that could occur due to scouring is the settlement of the bridge pier, eventually leading to undermining of the base and failure of the bridge. Gabion Mattress shall be applied for this defect as standard repair method. But if river bed shape is complicated, it is very difficult to put Gabion Mattress. In this case, Nylon Fiber Gabion shall be adopted as appropriate selection for installation of anti-scouring protection. Thus, protection against local scouring is intended to eliminate or minimize future damage to the bridge substructure.

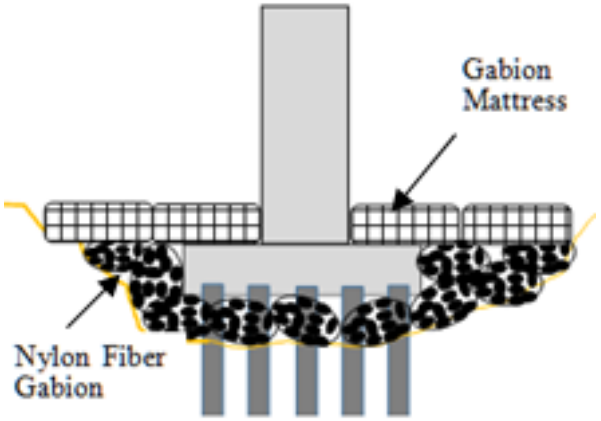


Fig. 10-5 Local Scouring around Pier

10-4-2 Application Criteria

Nylon Fiber Gabion is used for prevention of scour on pier foundation and other underwater structures. It consists of a bag body formed by knitted fabric made of nylon. The bag is filled with boulders or stones which are also used for conventional box-type zinc-coated wire gabions. The nylon fiber gabion is flexible and conforms to the shape where it is placed. The nylon netting allows water passage through bag body ensuring that pressure of flowing water does not affect the bag and keeping the scour prevention materials (boulders) from being carried or swept away by the water.

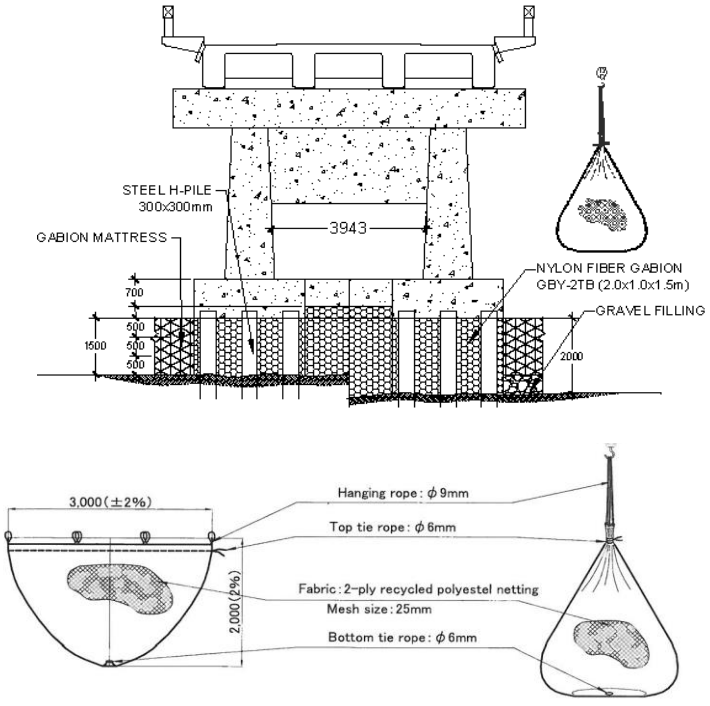


Figure 10-6 Application Requirement for Nylon Fiber Gabion

10-4-3 Work Sequence

(1) Place Boulders into Nylon Fiber Gabion Bag

Boulders to be used shall conform to requirements of Item 511 – Gabions and Mattresses of DPWH Standard Specifications. When filled, Nylon Fiber Gabion weighs 2 tons with equivalent size of 3m x 2m and volume of about 1.24 m3.

(2) Transport to Scoured Area

After installation of boulders, Nylon Fiber Gabion shall be transported to scoured area by backhoe.

(3) Place Nylon Fiber Gabion Using Backhoe

Using backhoe lay gabions in scoured portion. Continue laying up to designated elevation.

10-4-4 Required Materials and Tools/Equipment

10-4-4-1 Required Material

- Nylon Fiber Gabion
- Gabion Mattress

- Rock Fill (Boulders)
- Backfill Materials

10-4-4-2 Required Equipment

- Backhoe or Crane

10-4-5 Specification

10-4-5-1 Material Requirement

Nylon Fiber Gabion bag materials shall conform to the requirements of the specifications shown in Table 10-1.

Table 10-1 Specifications of Nylon Fiber Gabion Bag

Property	Test Method	Unit	Specifications
A. Tensile Strength			
1. Netting (25 mm mesh size)	ASTM D4268 / JIS A8960	N	≥ 450
2. Hanging Rope (9mm Ø)	ASTM D4268 / JIS L2707	kN	≥ 10
3. Top Tie Rope (6mm Ø)	ASTM D4268 / JIS L2704	kN	≥ 7
4. Bottom Tie Rope (6mm Ø)	ASTM D4268 / JIS L2704	kN	≥ 7
B. Elongation			
1. Netting (25 mm mesh size)	ASTM D4268 / JIS A8960	%	≥ 30 to ≤ 50
2. Hanging Rope (9mm Ø)	ASTM D4268 / JIS L2707	%	≤ 40
3. Top Tie Rope (6mm Ø)	ASTM D4268 / JIS L2704	%	≤ 45
4. Bottom Tie Rope (6mm Ø)	ASTM D4268 / JIS L2704	%	≤ 45

The material shall undergo quality tests and conform to the above specifications

10-4-5-2 Construction Requirement

(1) Excavation and Backfilling

The base for the gabions shall be excavated to the required extent and level. The excess area around the finally formed gabion shall be backfilled in accordance with the relevant provisions of the DPWH Standard Specifications. Each layer of backfill shall be compacted using an approved lightweight mechanical or vibratory compactor.

(2) Installation of Nylon Fiber Gabion

If scouring is heavily occurred, it is very difficult to apply to original gabion mattress underneath of pier footing. In this case, Nylon Fiber Gabion shall be applied for these locations as appropriate materials.

(3) Installation of Gabion Mattress

After installation of Nylon Fiber Gabion, gabion mattress shall be placed as surface layer. Requirement of installation is the same as that of gabion mattress, Item 511-Gabions and Mattresses.

(4) Backfilling

Backfill for the gabion mattress shall be in accordance with DPWH Standard Specifications Item 103.2.6.

The backfill shall be appropriately filled up evenly on all sides of the mattress. Each

layer shall extend to the limits of the excavation or to the natural ground.

10-4-6 Measurement and Payment

10-4-6-1 Method of Measurement

The works for this repair works shall be measured in accordance with DPWH Standard Specifications, Item 511-Gabions and Mattresses.

10-4-6-2 Basis of Payment

The quantity, measured as prescribed above, shall be paid in accordance with DPWH Standard Specifications, Item 511-Gabions and Mattresses.

APPENDIX A

COMPUTER-BASED PROGRAM

USER'S MANUAL

User's Manual

2nd Edition

2014

User's Manual of Computer-Based Program on Bridge Repair Manual

General

This manual which is divided into 4 sections, provides detail procedures on how to operate the Computer-based Program on Bridge Repair.

TCP (JICA-DPWH) developed the Bridge Repair Manual on November 2008 and developed the 2nd Edition which was released on 2014. Also, 2nd Edition of **Computer-Based Program (2nd CBM)** has been developed to complement 2nd Edition of Bridge Repair Manual.

This manual has the advantages as follows;

(1) It is easy to determine the repair method, specifications as well as sequence of repair.

(2) This manual provides Cost Estimate of main repair method.

(3) DPWH Engineers can save time in selecting appropriate repair method.

(4) DPWH Engineers can avoid inappropriate repair method.

1. Function of this Program

This program provides Bridge Repair Manual as well as Cost Estimate.

2. Installation of Software

This program requires the software which should be installed your computer.

Adobe Acrobat Version 8,9,10,11

Microsoft Excel 2003,2007,2010,2013

Microsoft Windows XP, Vista, 7 and 8 (for Windows 8, program installation may need adjustments)

3. Installing and Uninstalling 2nd CBM

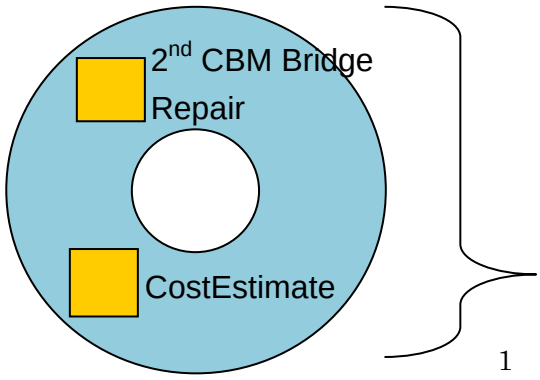
Installing

(1) Start your computer

(2) Insert the CBM Set-up CD. Then you can see two main folders as follows:
"2nd CBM Bridge Repair" and "CostEstimate".

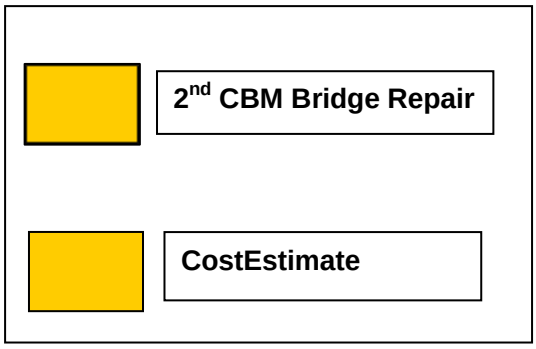
(3) Paste them to your computer's **Desktop**:

Program CD



Insert Program CD to your PC

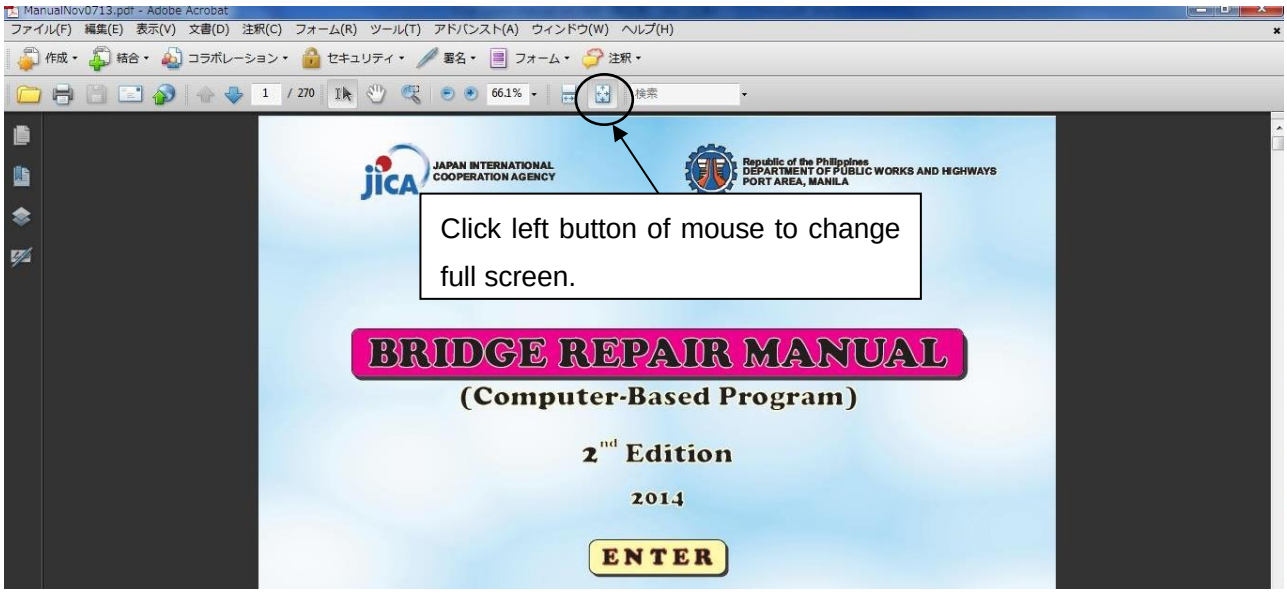
Copy to your computer Desktop



Starting

Open 2nd CBM Bridge Repair Main Folder. Double click "2nd CBM Program. pdf ". No need to open Sub-folder Reference Files.

The 2nd CBM program start. The screen shows Entrance of Bridge Repair Manual as below.



Click "Full Screen" button. The screen shows Full Screen as below. Right click goes to previous page and left click goes to next page. Click ESC button of your PC, then the screen goes back to Normal Screen.

Uninstalling

Delete "2nd CBM Bridge Repair" and "CostEstimate" folders from desktop

4. Procedure of this Manual

4.1 Enter

Click **Enter** button.

4.2 Main Menu

Computer display shows **Main Menu** as below, Routine Maintenance Repair, Major Maintenance Repair and Preventive Maintetance.

4.2.1 Routine Maintenance Repair has only one(1) button in this screen.

Routine Maintenance Repair button can directly proceed “COMPONENT OF ROUTINE MAINTENANCE”, “2-1. TYPE OF DEFECTS AND CAUSES” and “2-3. SCOPE OF ROUTINE MAINTENANCE REPAIRING METHOD” each bridge components.

4.2.2 Major Maintenance Repair has seven ((2) - (8)) buttons in this screen.

(2) **Major Maintenance Repair** button can proceed “COMPONENT OF MAJOR MAINTENANCE”, “3-1. TYPE OF DEFECTS AND CAUSES”, “3-2. PROCEDURE FOR SELECTING REPAIR METHOD” and “REPAIR METODS(CHAPTER 4-10)” each bridge components.

(3) **Type of Defects** button can directly proceed “3-1. TYPE OF DEFECTS AND CAUSES”,, “3-2. PROCEDURE FOR SELECTING REPAIR METHOD” and “REPAIR METODS(CHAPTER 4-10)” each bridge components.

(4) **Procedure for Selecting Repair Method** button can directly proceed “3-2. PROCEDURE FOR SELECTING REPAIR METHOD” and “REPAIR METODS(CHAPTER 4-10)” each bridge components.

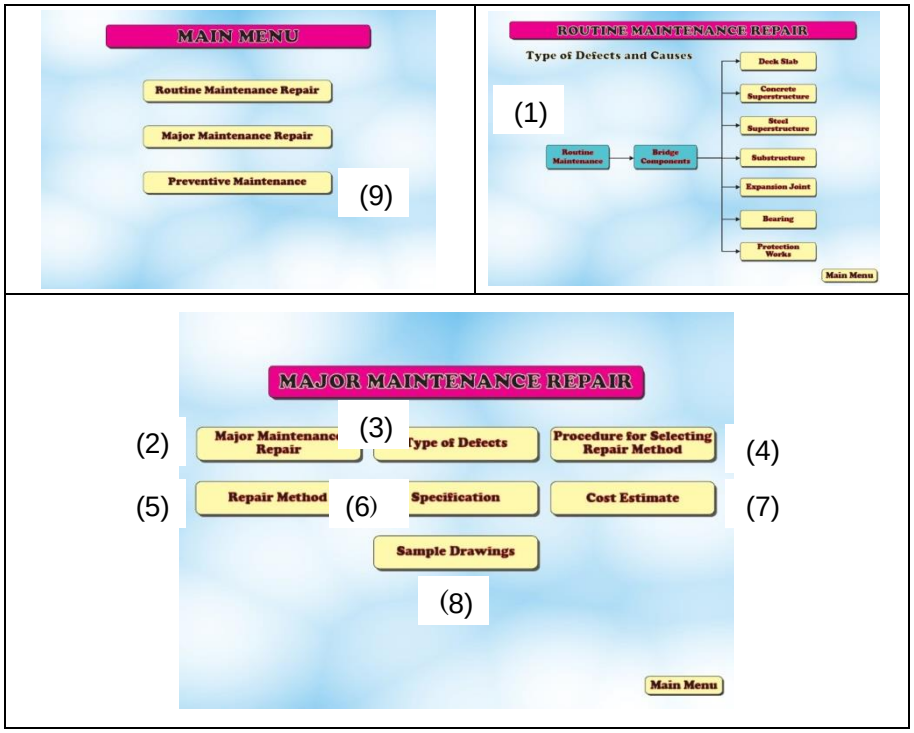
(5) **Repair Method** button can directly proceed “REPAIR METODS(CHAPTER 4-10)” each bridge components.

(6) **Specification** button can directly proceed Specification each “REPAIR METODS(CHAPTER 4-10)”

(7) **Cost Estimate** button can detect repair cost each type of Repair Method by Microsoft Excel file.

(8) **Sample Drawings** button can show standard drawing for each type of Repair Method.

This function will be developped in the future .



Each button's function is discribed in Table4-2 .

Table 4.2 The procedure of this program is going each item through as this table.

Name of Button	Bridge Components	Defects	Criteria & sellecting	Bridge Repair Method	Specification	Cost Estimation
(1) Routine Maintenance Repair	2.1 ● →	2.1 ● →		2.3 ●		
(2) Major Maintenance Repair	3.1 ● →	3.1 ● →	3.2 ● →	Chap. 4 – 10 ●		
(3) Type of Defects		3.1 ● →	3.2 ● →	●		
(4) procedure for Sellecting Repair Method		3.1 ● →	3.2 ● →	●		
(5)Repair Method				Chap. 4 – 10 ●		
(6) Specification				Chap. 4 – 10 ● →	●	
(7) Cost Estimat				Chap. 4 – 10 ● →		●

(8) Sample Drawing						
(9) Preventive Maintenance			3.2 •	Chap. 4 – 6 •		

2.1 TYPE OF DEFECTS AND CAUSES

2.3 SCOPE OF ROUTINE MAINTENANCE AND REPAIRING METHOD

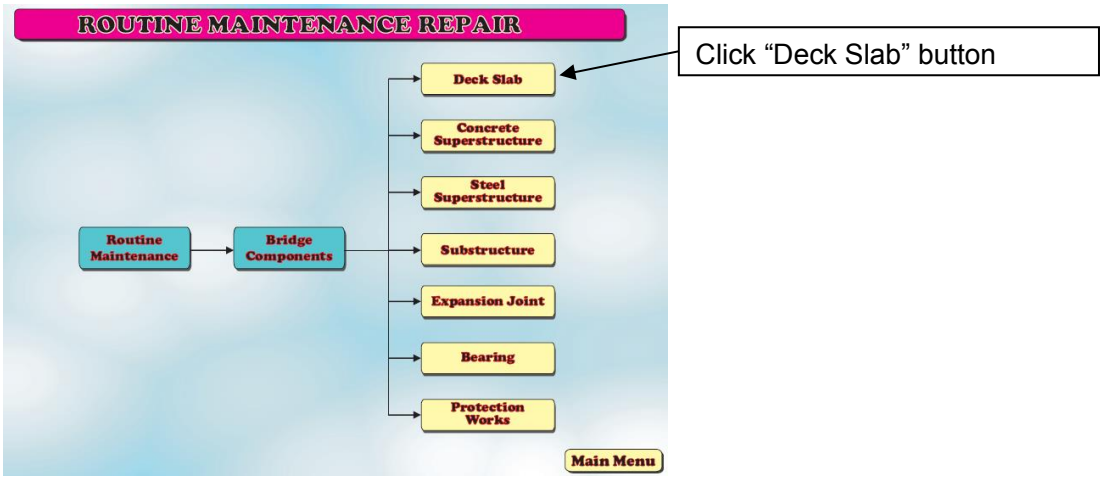
3.1 TYPE OF DEFECTS AND CAUSES

3.2 PROCEDURE FOR SELECTING REPAIR METHOD

Chapter 4-10 REPAIR METHOD

4.3 "Routine Maintenance Repair" button

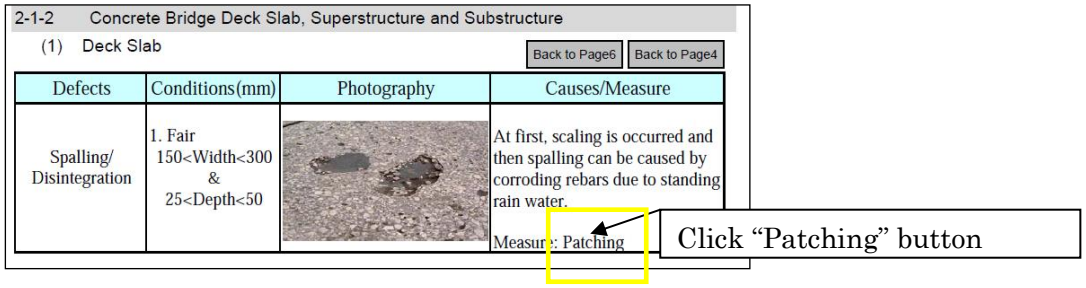
(1) Click "Routine Maintenance Repair" button. This screen appears on the display.



(2) Click "component" button. The screen shows Chapter 2. 2-1. TYPE OF DEFECTS AND CAUSES.

Back to page button can return to bridge components screen or Main menu.

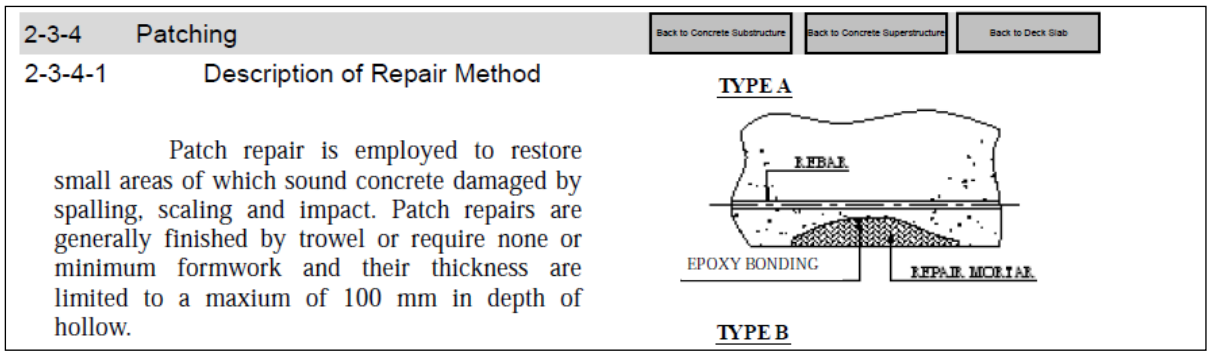
For example, click "Deck Slab" button. The program shows 2-1-2 Concrete Bridge Deck Slab, Superstructure and Substructure as below.



(3) Click" Measure" button. The screen shows Chapter 2. 2.3 SCOPE OF ROUTINE MAINTENANCE AND REPAIRING METHOD.

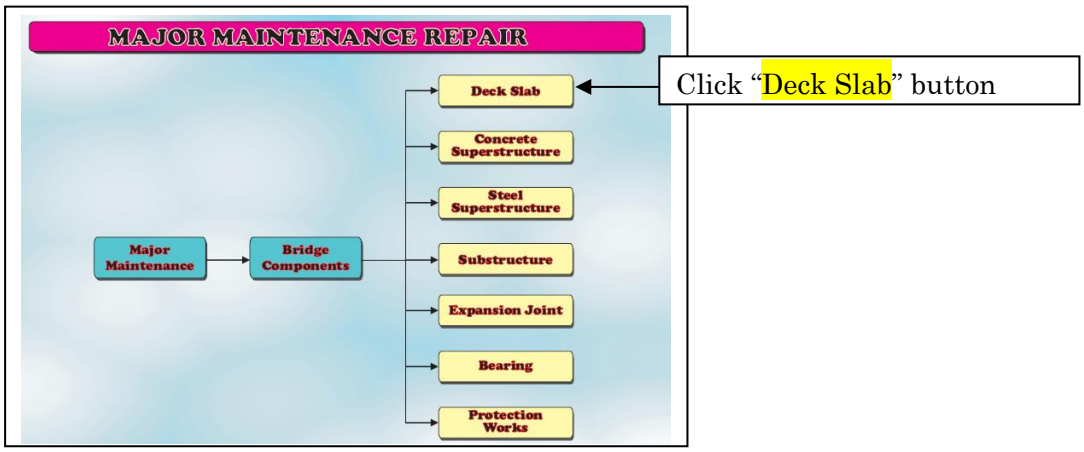
Back button can return to each bridge components screen or Main menu.

For example, click" Patching" button. The program shows 2-3-4 Patching for Routine Maintenance.



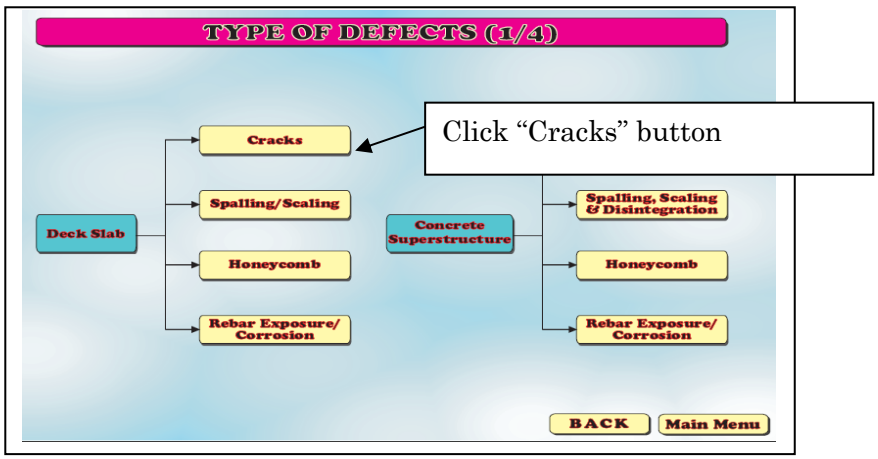
4.4 "Major Maintenance Repair" button

(1) Click "Major Maintenance Repair" button. This screen appears on the display. Main Menu button can return to Main menu.



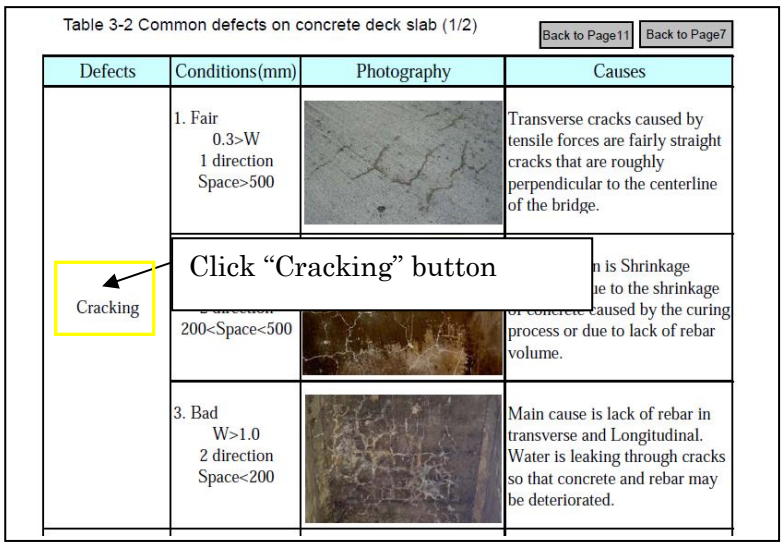
(2) Click "component" button. The screen shows Type of Defects for each bridge components. Main Menu button can return to Main menu. Back button can return to above menu.

For example, click "Deck Slab" button. The screen shows Type of Defects for Deck Slab.



(3) Click “Defects” button. The screen shows Chapter3.3-1Types of DEFECTS AND CAUSES. Back to page button can return to “Type of Defects” screen or Main menu.

For example, click “Cracks “button. The screen shows 3-1 Type of Defects and causes.



(4) Click “Defects” button. The screen shows Chapter 3. 3-2. PROCEDURE FOR SELECTING REPAIR METHOD.

For example, Click “Cracking” button.

The screen shows 3-2 procedure for selecting repair method. You can select the Bridge Repair Method for Deck Slab.

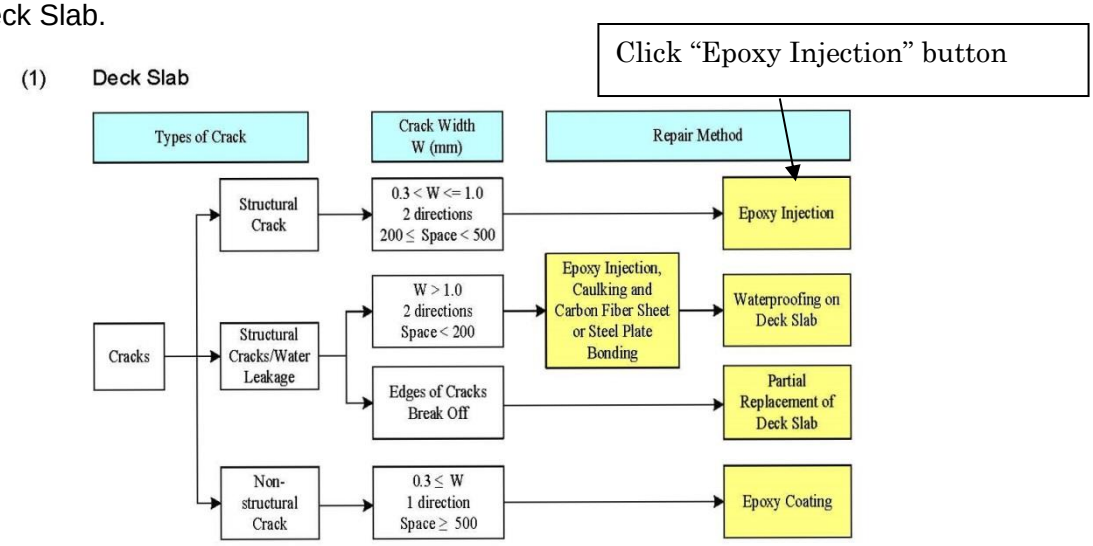
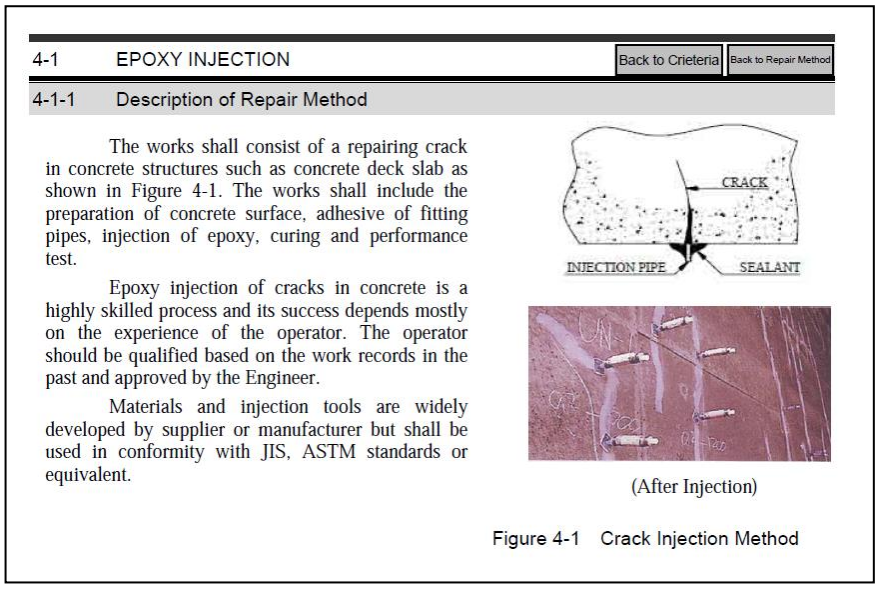


Figure 3-1 Selection Procedure of Repair Method for Deck Slab Due to Cracks

(4) Click "Repair Method" button. The screen shows chapter 4 – 10 REPAIR METHODS.

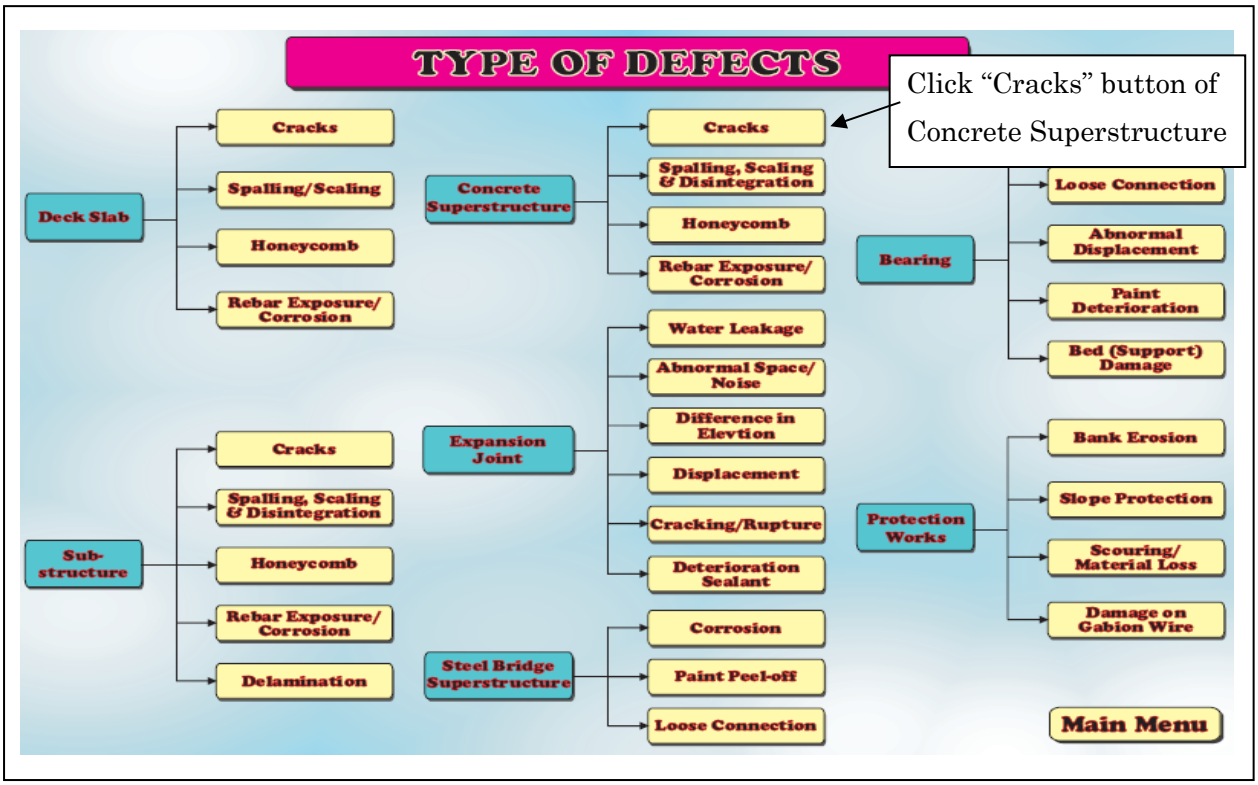
Back button can return to "procedure for selecting repair method" screen or Main Menu.

For example, click "Epoxy Injection" button. The screen shows 4-1 "EPOXY INJECTION" Method



4.5 "Type of Defects" button

(1) Click "Type of Defects" button in Main Menu. The screen shows "Type of Defects" menu as below. Main Menu button can return to Main menu.



(2) For example, click "Cracks of Concrete Superstructure" button. The screen shows Table 3-4 Common concrete defects of bridge superstructure (1/2) as below. If you want to proceed more, you can see as same as 5.3 Major Maintenance Repair described.

Back button can return main menu.

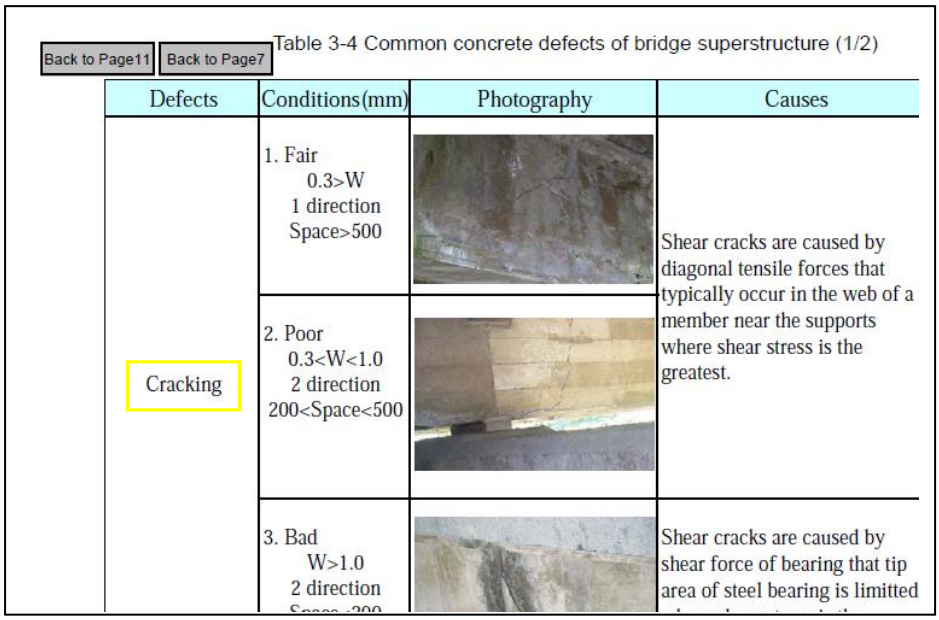

Back to Page11 Back to Page7

Table 3-4 Common concrete defects of bridge superstructure (1/2)

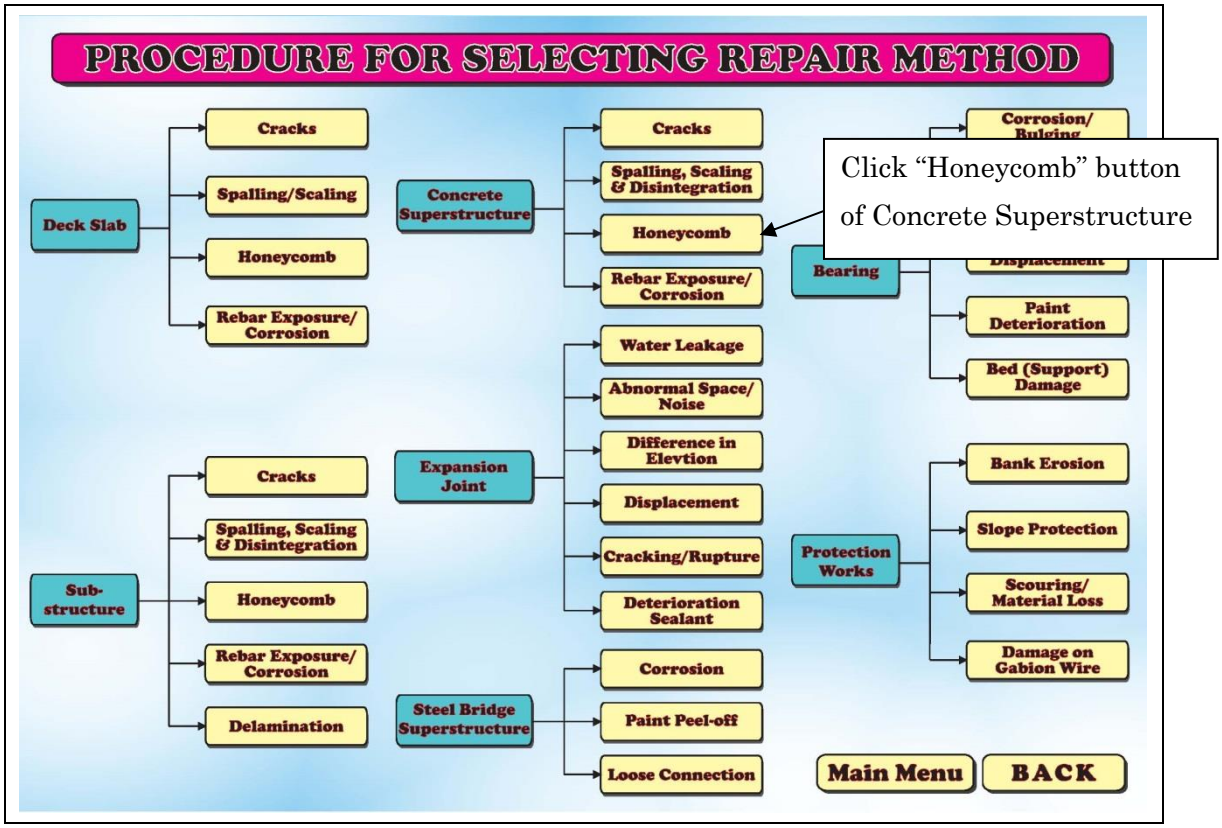
Defects	Conditions(mm)	Photography	Causes
Cracking	1. Fair 0.3>W 1 direction Space>500		Shear cracks are caused by diagonal tensile forces that typically occur in the web of a member near the supports where shear stress is the greatest.
	2. Poor 0.3<W<1.0 2 direction 200<Space<500		
	3. Bad W>1.0 2 direction		Shear cracks are caused by shear force of bearing that tip area of steel bearing is limitted

4.6 ”Procedure for Selecting Repair Method”

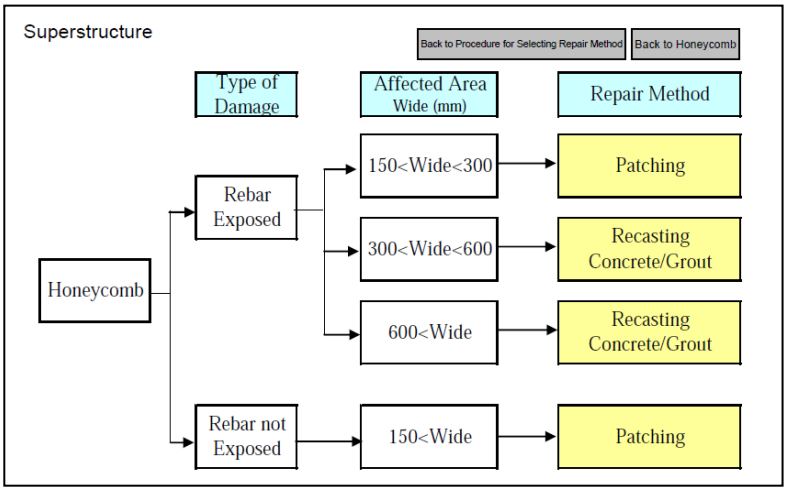
(1) Click “Procedure for Selecting Repair Method” button. The screen shows “Procedure for Selecting Repair Method” menu as below.

Main Menu button can return to Main menu.

Honeycomb for concrete superstructure



(2) For example, Click “Honeycomb” button of Concrete Superstructure. The screen shows 3-2 Procedure for Selecting Repair Method 3-2-4 (2) Honeycomb on Concrete Superstructure as below.



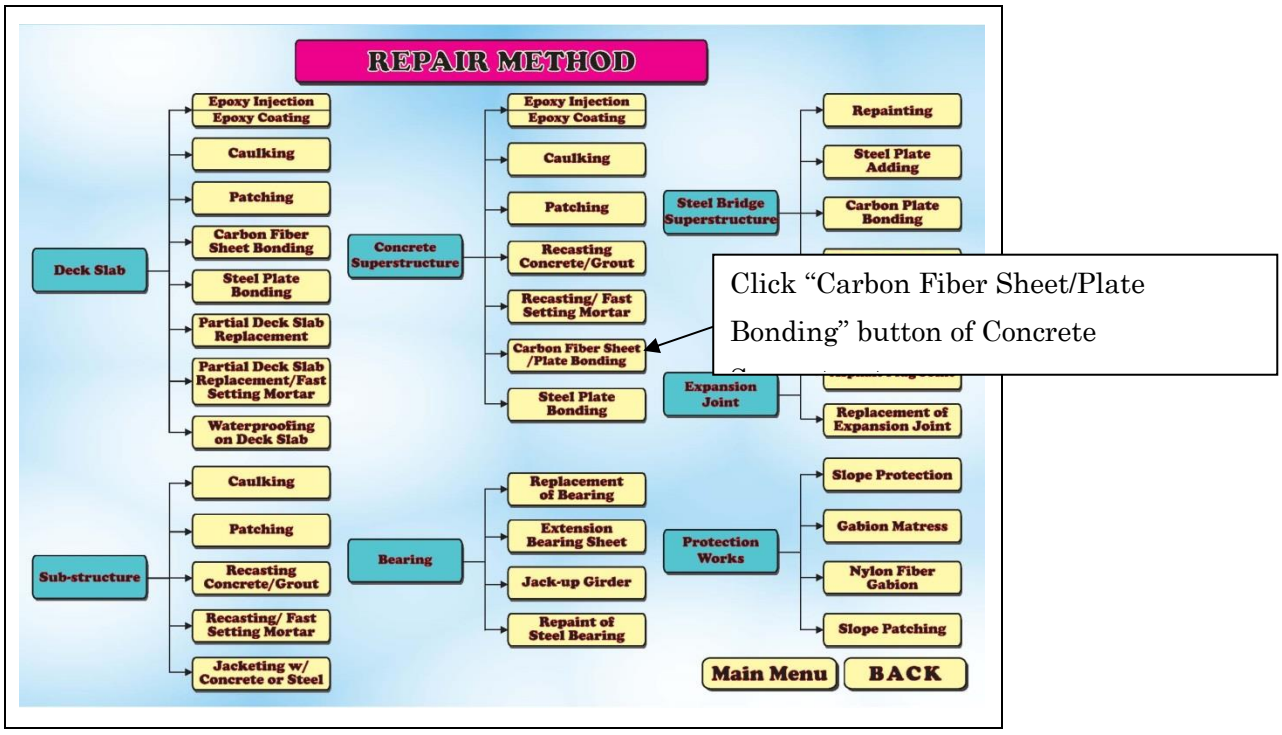
“Back” button can return to before screen.

4.7 “Repair Method” button

(1) Click “Repair Method” button. This screen appears on the display.

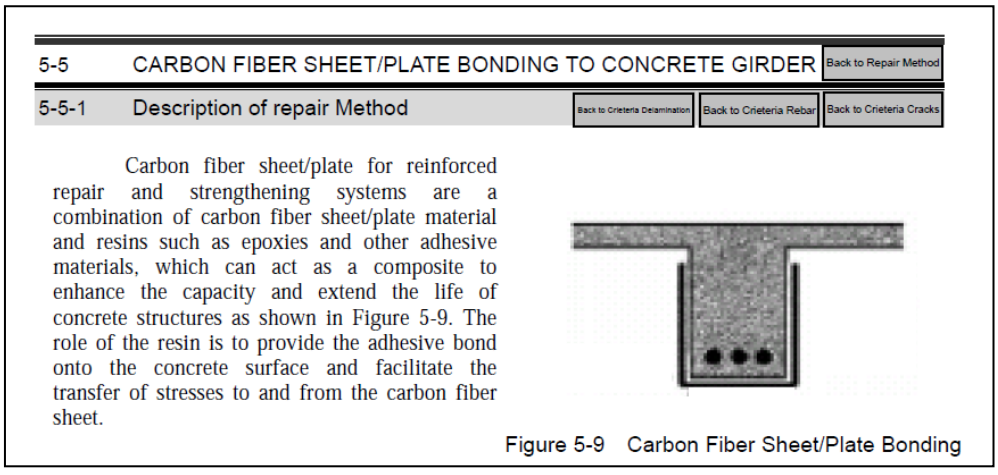
This menu is to show all Repair Method of Major maintenance. The button is to show directly each specified Bridge Repair Method.

Main Menu button can return to Main menu.



(3) Click “REPAIR METHOD” button. The screen shows Chapter 4 to 10 all Repair Methods. For example, click “Carbon Fiber Sheet/Plate Bonding to concrete girder” button. The screen shows 5-5 Carbon Fiber Sheet/Plate Bonding to Concrete Girder as below.

Back button can return to one step before screen.

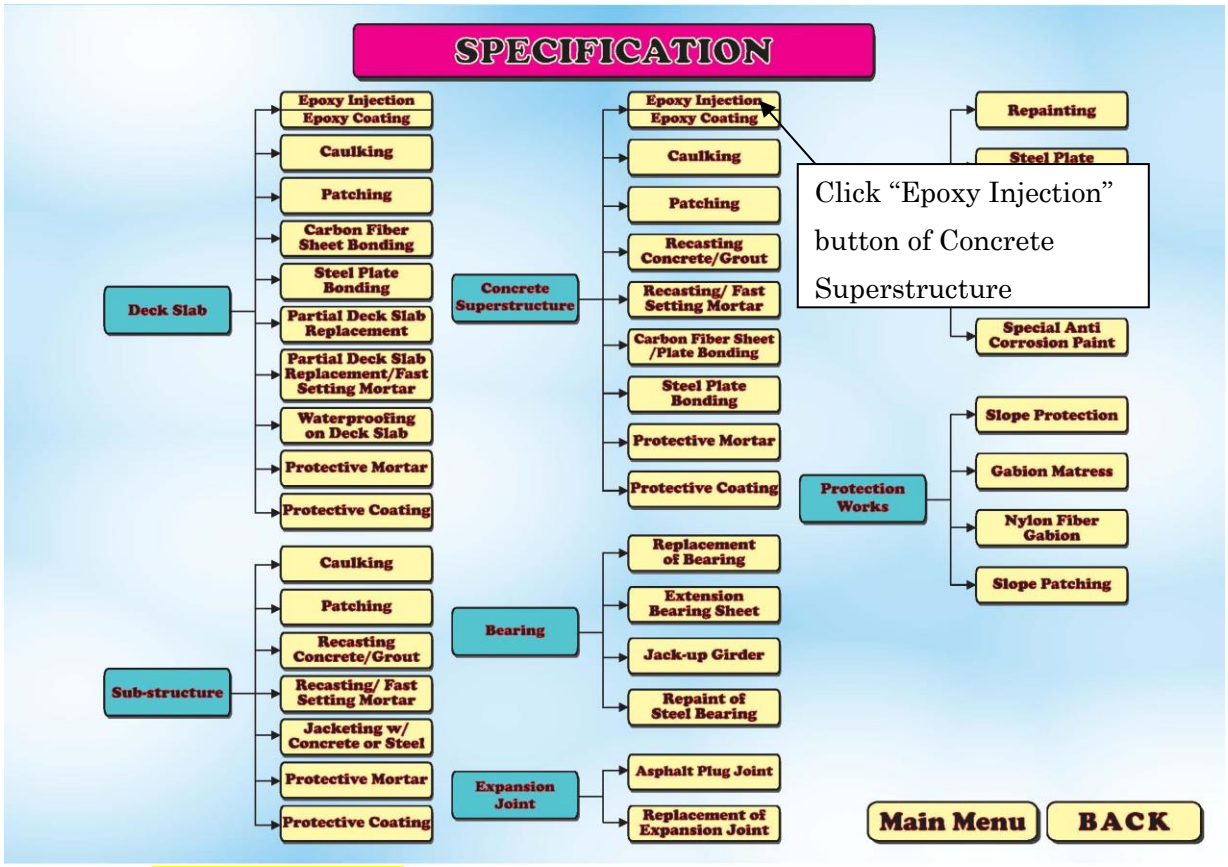


4.8 “Specification” button

(1) Click “Specification” button. This screen appears on the display.

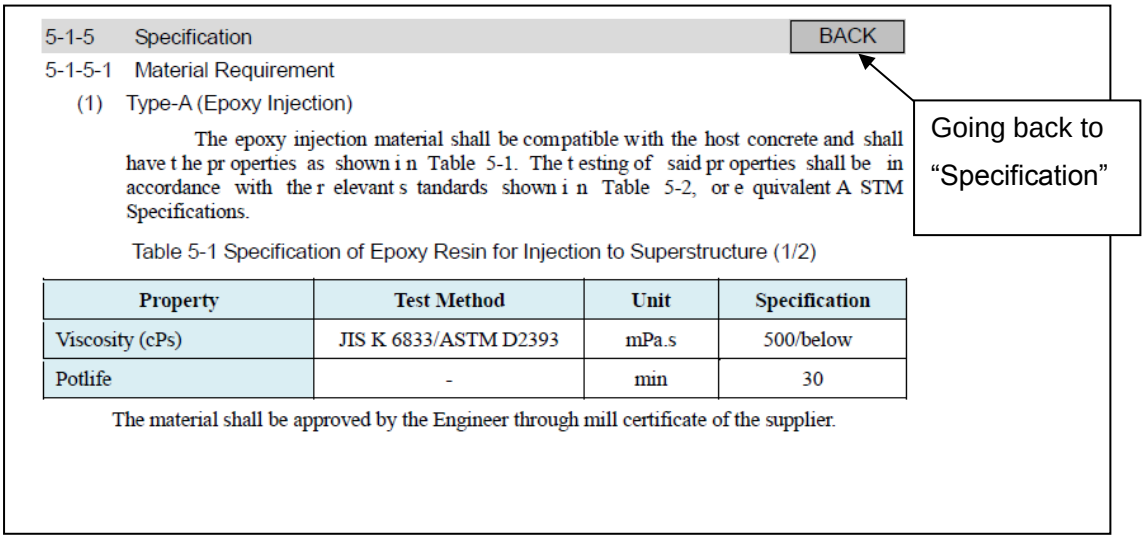
This button is to jump from each Repair Method to specified Specification directly.

Main Menu button can return to Main menu.



(2) Click “REPAIR METHOD” button. The screen shows Chapter 4 to 10 all Repair Methods. “BACK” button can return to “Specification” Menu.

For example, Click “Epoxy Injection” for concrete superstructure. The screen shows 5-1 Epoxy Injection 5-1-5 Specification as below.



4.9 “Cost Estimate”

(1) Click “Cost Estimate” button.

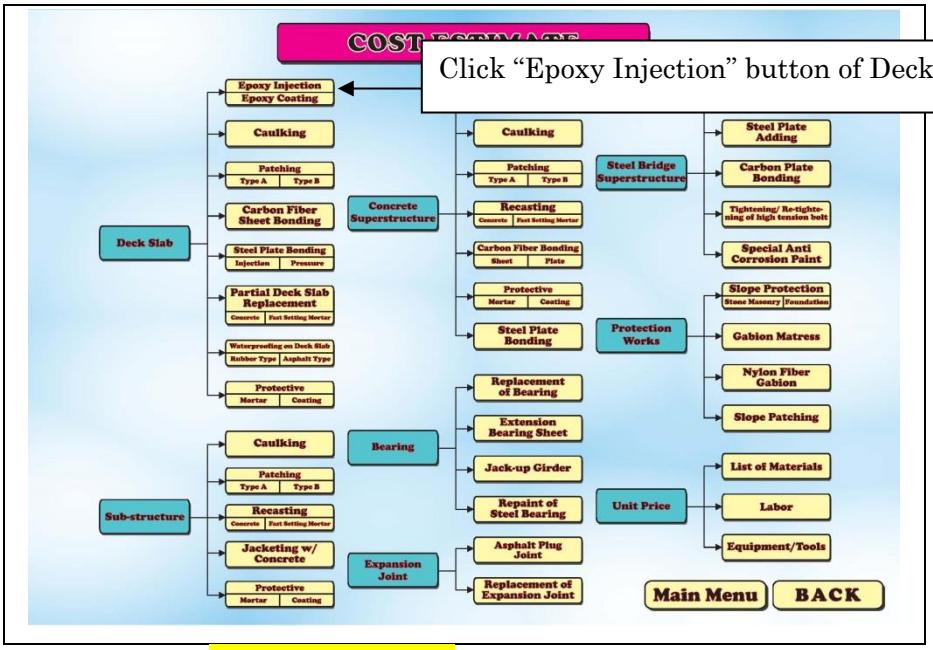
(2) This screen is shown as below.

(3) Click repair method for each bridge components.

(4) The program jumps to Excel file from pdf file.

This button is to compute cost estimation from selecting Repair Method by using Excel tables.

Main Menu button can return to Main menu.



(5) Click “REPAIR METHOD” button. The screen shows Excel file of Cost Estimate for Chapter 4 to 10 all Repair Methods.

For example, click “Epoxy Injection” of Deck Slab button. The screen shows Excel file

as below. You can select any other Repair Method to compute cost estimation.

If you close Excel file, the screen shows “Cost Estimate” Menu again.

Cost Estimate for Epoxy Injection

Deck Slab

No.	Description
1	Equipment/ Tool Cost
	Miscellaneous tool (Labor cost x 20%)
	Sub-total

4.10 “Sample Drawings”

(1) Click “Sample Drawing” button.

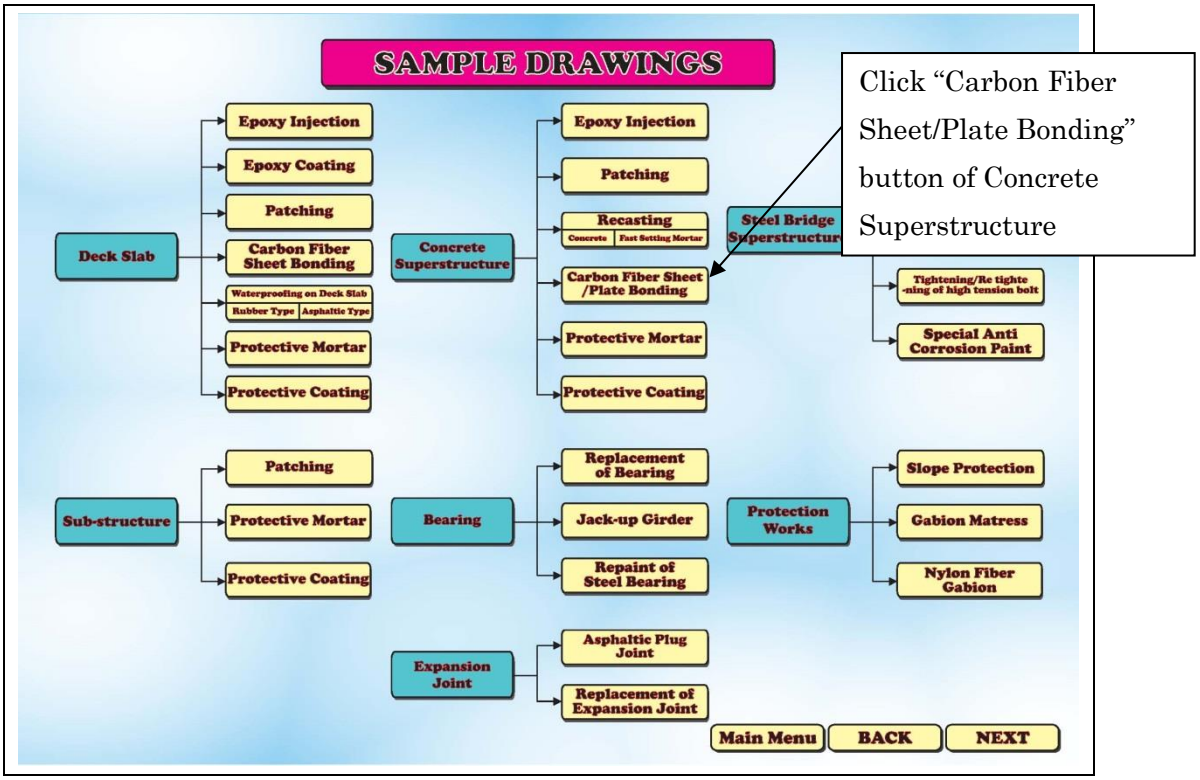
(2) This screen is shown as below.

(3) Click repair method for each bridge components.

(4) The program jumps to SAMPLE DRAWINGS.

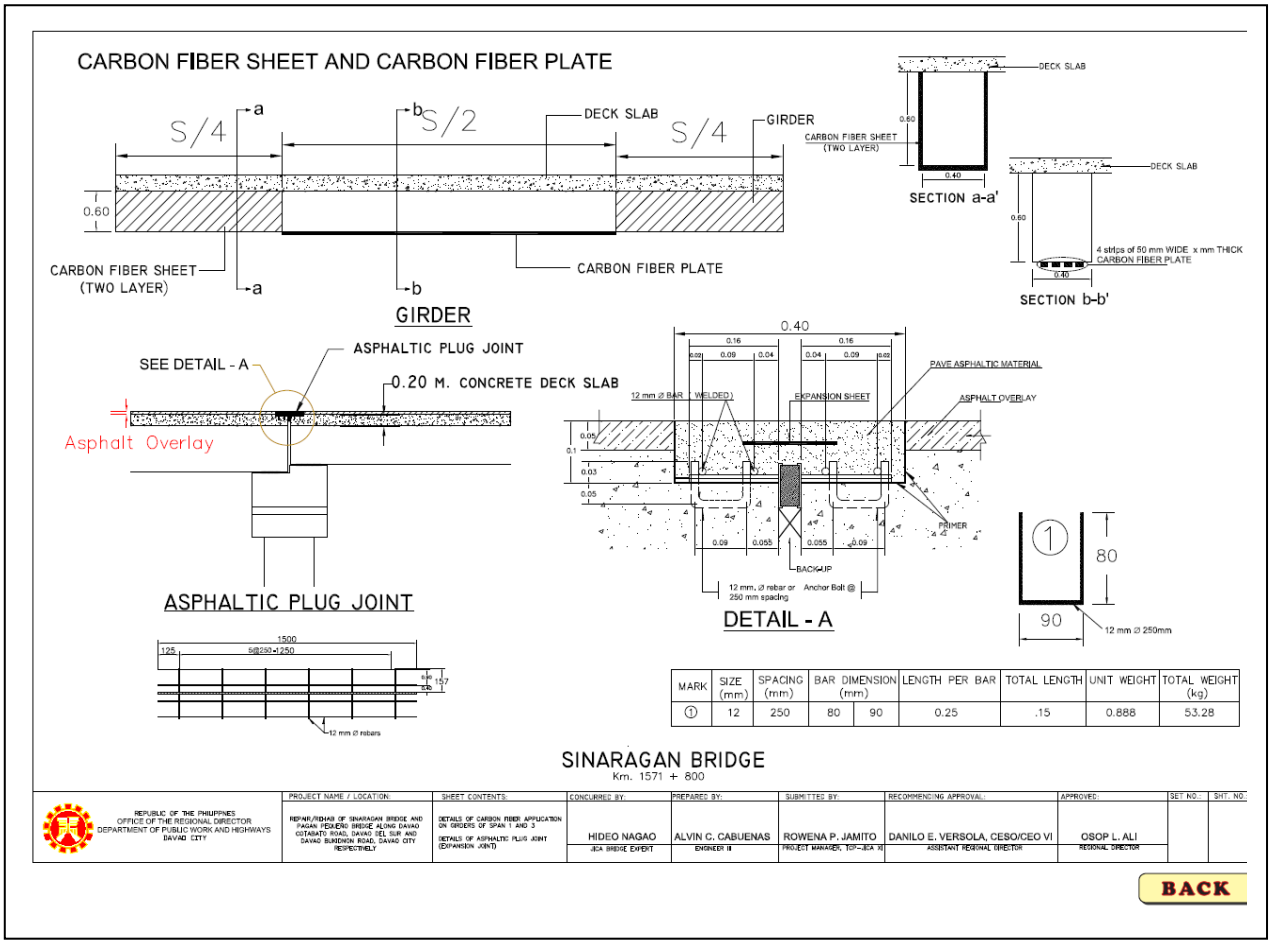
This button is to show Sample Drawings regarding to selecting Repair Method.

Main Menu button can return to Main menu.



(6) Click "REPAIR METHOD" button. The screen shows Chapter 4 to 10 all Repair Methods. For example, click "Carbon Fiber Sheet/Plate Bonding to concrete girder" button. The screen shows Sample Drawing of Carbon Fiber Sheet/Plate Bonding to Concrete Girder as below.

Back button can return to one step before screen.



MARK	SIZE (mm)	SPACING (mm)	BAR DIMENSION (mm)		LENGTH PER BAR	TOTAL LENGTH	UNIT WEIGHT	TOTAL WEIGHT (kg)
①	12	250	80	90	0.25	.15	0.888	53.28