Appendix 2. Major Repair Methods Plates

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

Table 5-1 Major Repair Methods

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

MAJOR REPAIR METHODS

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

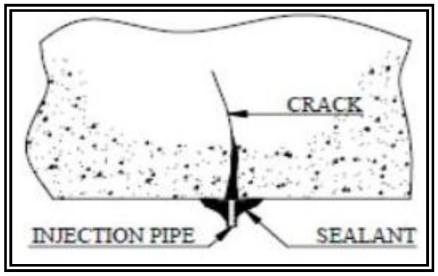
1. Work description

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

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

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

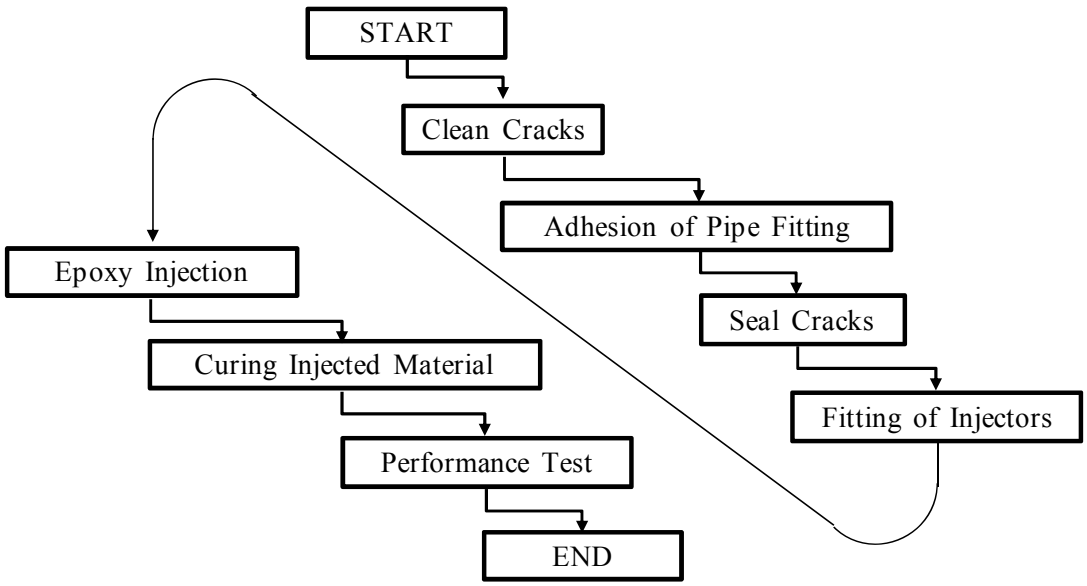
Figure 3-1-1 Epoxy Injection Method



2. Work sequence

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

Figure 3-1-2 Work Sequence



MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack on Concrete**	**PLATE 3-1**
Remedial Measure	**Crack Injection**	

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

1) Equipment/Tools

The following are necessary for Crack Injection:

-Epoxy Injection Pump or Gun

-Power Disc Grinder/Cutter

-Portable Generator -Brush etc.

2) Material

The following materials are used for Crack Injection:

-Epoxy Resin

-Sealant

-Injection port

4. Requirement, Specifications

4-1 Material

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

1) Epoxy Resin

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

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

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

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

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

2) Sealant

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

accordance with the listed standards or equivalent ASTM Specifications.

Table 3-1-3 Specifications of Sealant (Putty) for Crack Injection (for Deck Slab)

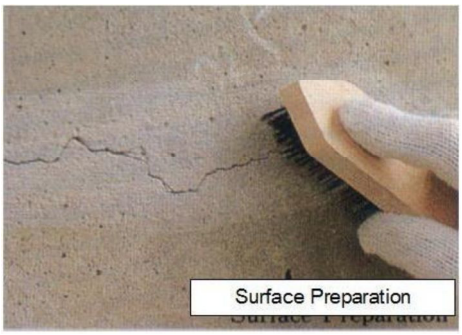
Property	Test Method	Unit	Specification
Specific Gravity	ASTM D792	-	1.50±0.30
Bond Strength	ASTM C882	N/mm^2	15/above
Compressive Strength	ASTM D695M	N/mm^2	50 /above
Flexural Strength	ASTM D790M	N/mm^2	15 /above
Tensile Shear Bond Strength	ASTM D1002	N/mm^2	10 /above

4-2 Work requirement

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

1) Clean the cracks.

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



The intention of this work is to fill and seal these cracks, particularly those found on concrete bridges. The extent of the cracks shall be indicated by the Contractor and shown on drawings. The detail of the quantities shall be marked out on the concrete elements, and agreed with the designated Engineer prior to proceeding. The Engineer may adjust the extent of the work as the project proceeds, based on actual conditions.

Loose or spalled concrete, grease, traces of paints, oil or other contaminants shall be marked out and removed using wire brushes, grinding wheels or power brush.

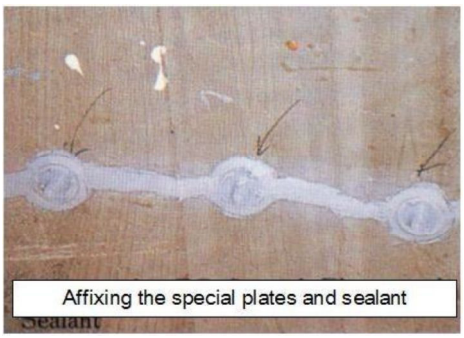
All cracks shall be thoroughly cleaned using clean, oil-free compressed air. Both the concrete surface and the cracks shall be allowed to dry thoroughly before commencing the crack injection.

2) Adhesion of pipe fitting

Connect the terminal of the injector to the pipe

fittings. Pipe fittings are bonded with the adhesive to the crack center for injecting epoxy. Spacing of the pipes varies between 150mm to 500 mm, depending on the width and depth of the cracks. The first and last pipe fitting are set at or near the bottom and top, respectively.

The pipe fittings shall be fixed at certain intervals along the length of each crack. The distance between each fitting shall be as shown on the drawings, considering the width and depth of crack, for approval of the Engineer.



Affixing the special plates and sealant

The surface sealant shall be moisture tolerant putty with good adhesion to concrete. This is supplied in two components namely, the base resin and the hardener. These are weighed according to the specified mix proportions of the manufacturer. The mixing process is continued until a uniform paste is obtained.

The mixed surface sealant shall be applied to the metal base of each pipe fitting. They shall be pressed firmly into place and held until secured. In this way, all the fittings shall be fixed along the length of the crack. The surface of the cracks between the fittings shall be sealed with a band of surface sealant, measuring 50 mm wide and 2 to 3 mm thick. A complete seal shall be made around the metal bases of each pipe fitting. The prepared cracks shall be allowed to cure for at least 12 hours.

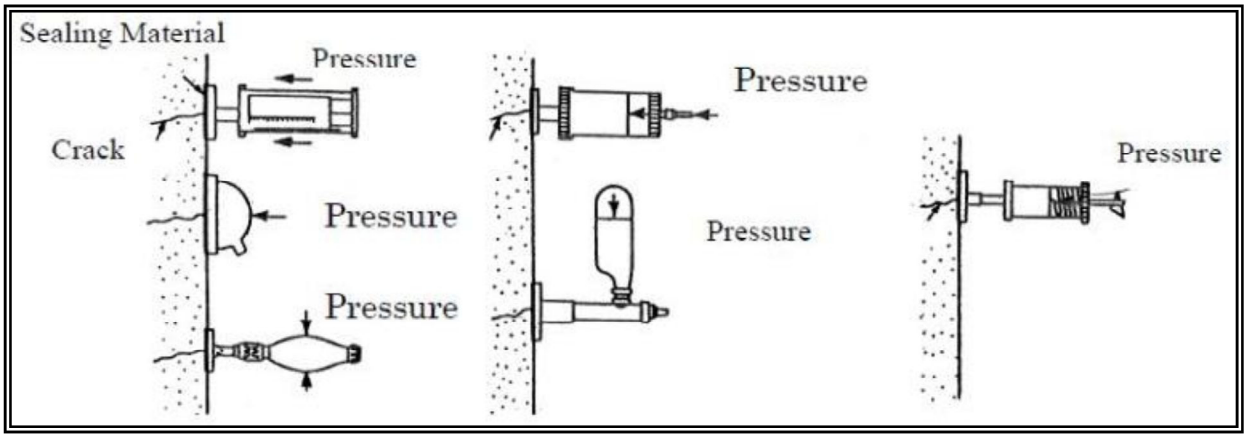
3) Epoxy Injection

Epoxy shall be injected using air-activated injecting guns as shown in Figure 3-1-3. Injection is performed on the pipe fitting. Duration of the injection operation shall be in accordance with the supplier's instructions.

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack on Concrete**	**PLATE 3-1**
Remedial Measure	**Crack Injection**	

Figure 3-1-3 Crack injection method



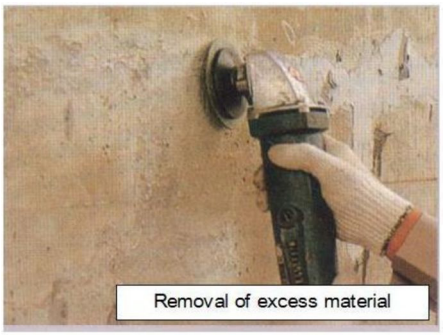
Each crack shall be treated in a single, continuous operation. Sufficient materials shall therefore be readily available prior to the commencement of work. The preparation, mixing and application of the materials shall be undertaken in strict compliance with the manufacturer's recommendations and approved by the Engineer. Before the works commence, the Contractor should ensure that all necessary tools and equipment are on site.

The materials shall not be used without the approval of the Engineer when the ambient temperature is at or below 5^{o}C or is above 35^{o}C. Only intact package of epoxy resin shall be used for each injection purpose. No part packs or on-site batching will be allowed under any circumstances.

In all operations of storage, mixing and application, the Contractor shall comply with the health and safety standards of the Engineer and the relevant governing rules and regulations as well.

4) Curing

The epoxy system shall be allowed to cure undisturbed for twenty four (24) hours. The pipe fittings and bands of surface sealant shall then be removed. Any damaged areas shall be made good to the satisfaction of the Engineer-in-Charge.


Removal of excess material

5) Performance Test

Low Frequency Pulse Velocity Ultrasonic Inspection will be determined if the epoxy resin has penetrated the full depth of the crack. If incomplete penetration is revealed from this test, the work has to be repeated on the Contractor's expense.

5. Method of Measurement and Payment

5-1 Method of Measurement

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

5-2 Basis of Payment

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

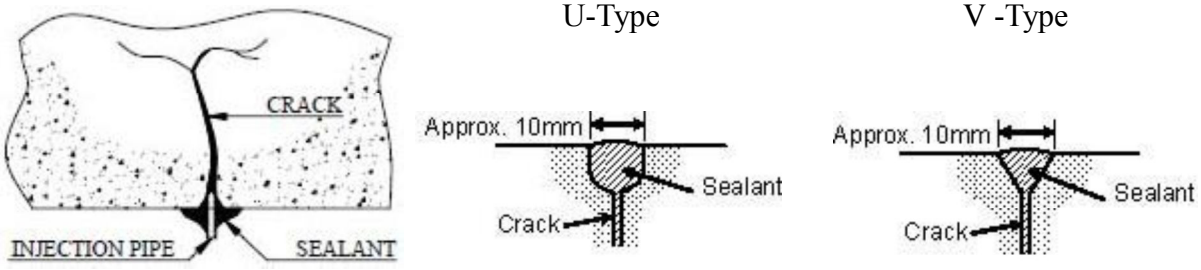
Pay Item No.	Name	Unit of Measurement
3-1	Crack Injection	Linear Meter (m)

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

1. Work description

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

Figure 3-2-1 Type of Filling



2. Application criteria

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

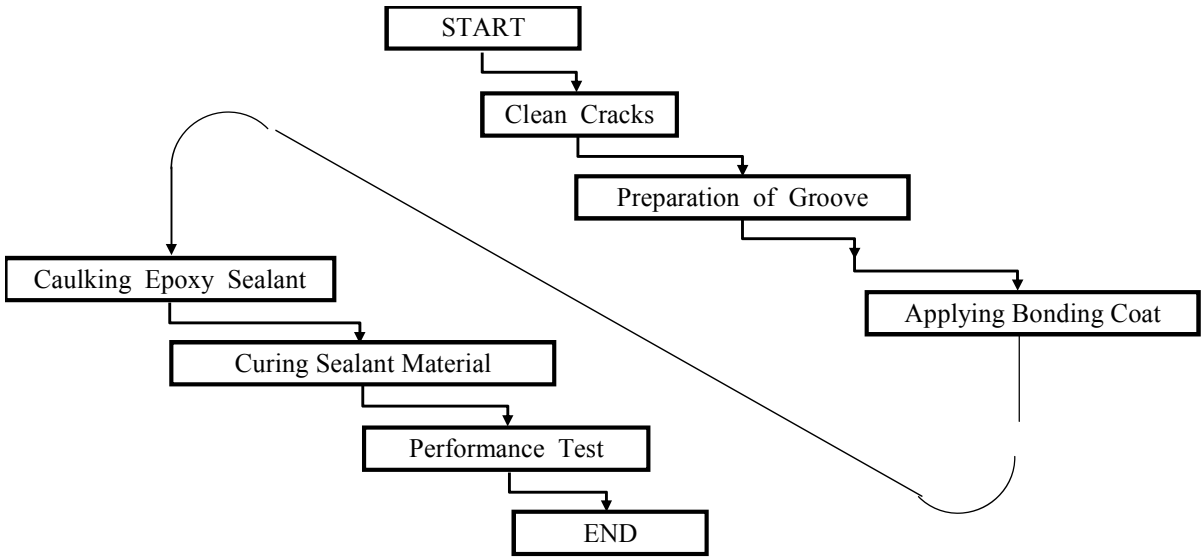
Cracks wider than 0.5 mm generally require epoxy based injection material (mix of epoxy and mineral filler).

3. Work sequence

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

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

Figure 3-2-2 Work Sequence



4. Required Equipment/Tools and Material

1) Tools/Equipment

The following tools/equipment are necessary for Filling:

-Caulking Gun

-Power Disc Grinder/Cutter

-Portable Generator

-Brush

2) Materials

The following materials are necessary for Filling:

- Epoxy Primer
- Sealant

5. Requirements, Specifications

5-1 Material

The material shall be approved by the Engineer through mill certificate of the supplier. Testing of materials shall be in accordance with the relevant standards shown or equivalent ASTM Specifications.

1) Epoxy bonding primer

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

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

Table 3-2-1 Specifications of Epoxy Bonding Primer

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

2） Sealant

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

Table 3-2-2 Specification of Epoxy Based Sealant

Property	Test Method	Unit	Specification
Specific Gravity	ASTM D792	-	1.5±0.3
Elongation	ASTM D638	%	50
Bond Strength to Concrete Dry /Wet	ASTM C882	$N/mm2$	3.0

5-2 Work requirement

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

1) Preparation of concrete

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

Blow away the residual water or solvent in the crack with filtered (dust and oil free) compressed air and allow adequate time for drying air. The intention of this work is to fill and seal these cracks, particularly those found on concrete bridges. The extent of the cracks shall be indicated by the Contractor and shown on drawings. The detail of the quantities shall be marked out on the concrete elements, and agreed with the designated Engineer prior to proceeding.

The Engineer may adjust the extent of the work as the project proceeds, based on actual

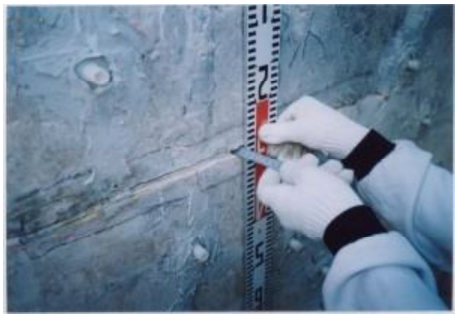
conditions.

Loose or spalled concrete, grease, traces of paints, oil or other contaminants shall be marked out and removed using wire brushes, grinding wheels or power brush as cleaning devices.

All cracks shall be thoroughly cleaned using clean, oil-free compressed air. Both the concrete surface and the cracks shall be allowed to dry thoroughly before commencing the injection.

2) Preparation of Groove

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



3) Applying bonding coat

The concrete surface of groove to which the bonding coat is to be applied shall be wet using potable water to achieve a moisture condition such that the concrete will not absorb moisture from the mortar. The wetting period will depend upon the substrata condition and the bonding coat manufacturer's recommendations, subject to Engineer's satisfaction.

The surface shall then be left wet until the free water has evaporated before the bonding coat is applied. Using a brush, the coat shall be applied to the exposed concrete surface.

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

4) Caulking epoxy sealant

The mixed sealant shall be applied into the groove along the cracks by a caulking gun. A complete seal shall be made around the metal bases of each port. The applied sealant as a caulking shall be allowed to cure for at least 12 hours.

The sealant material shall be selected in consideration with the crack movement which should be calculated taking into account the applied loads, shrinkage and temperature variations.

The Contractor shall propose suitable sealant material based on the study on the crack movement, subject to Engineer's approval.

The preparation, mixing and application of the sealant materials shall be undertaken in strict accordance with the manufacturer's recommendations.

The Contractor is to ensure that all necessary tools and equipment are on site until the works commence. In all operations of storage, mixing and application, the Contractor shall comply with the health and safety recommendations of the Engineer and the relevant governing rules and regulations.

5) Curing

After the crack is sealed, the sealant shall be allowed to cure for twelve (12) hours and shall be let undisturbed for this time.

6) Performance test

Low Frequency Pulse Velocity Ultrasonic Investigation shall be used to determine if the epoxy sealant has penetrated to the base of the groove. If incomplete penetration is revealed by investigation, such conditions shall be reworked at cost to the Contractor.

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

6. Method of Measurement and Payment

6-1 Method of Measurement

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

6-2 Basis of Payment

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

Pay Item No.	Name	Unit of Measurement
3-2	Crack Filling	Linear Meter (m)

MAJOR REPAIR METHODS		
Defect/Deficiency	**Spalling, Abnormal Anchorage**	**PLATE 3-3**
Remedial Measure	**Hand applied Mortar (A) & (B)**	

1. Work description

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

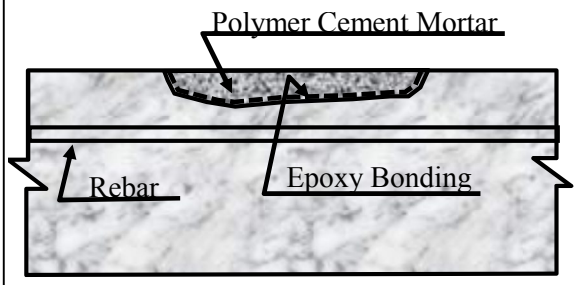
Hand applied Mortar repair is classified into two types as shown in Figure 3-3-1, considering defective area and surface.

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

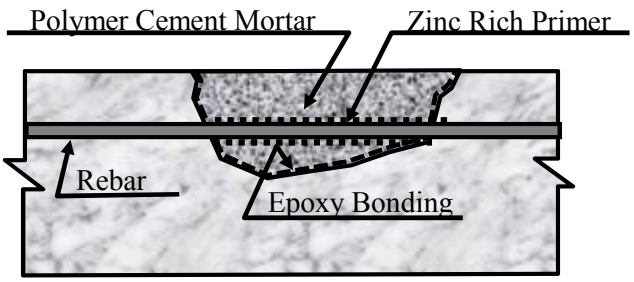
Hand applied Mortar repairs may be composed of Polymer cement mortars or non-shrinkage cement mortars depending on the type of patching, location and extent of damage.

Figure 3-3-1 Hand applied Mortar

i. Hand applied Mortar (A)



ii. Hand applied Mortar (B)



2. Application Criteria

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

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

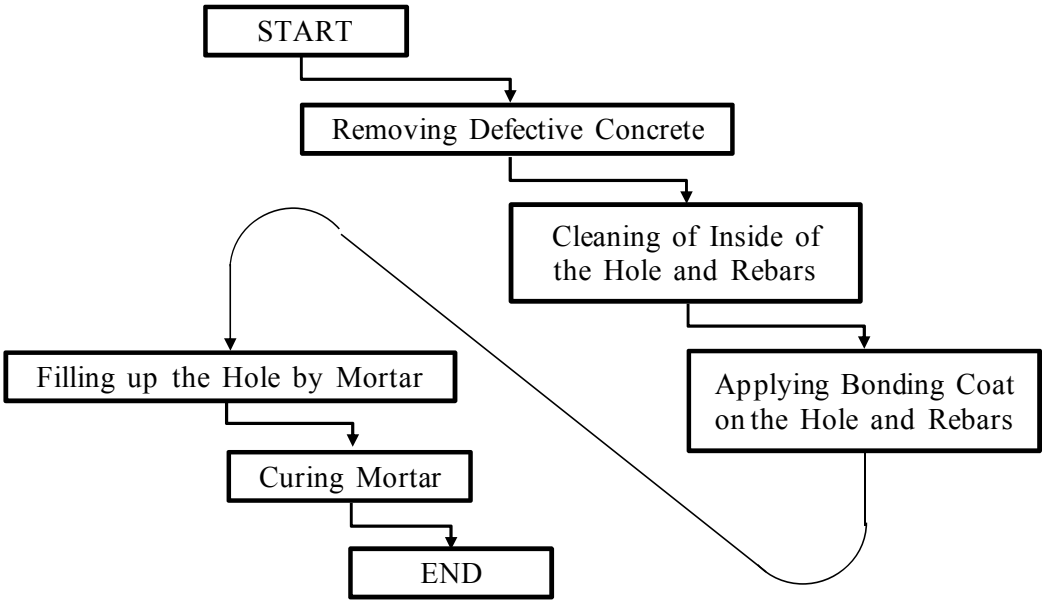
To keep good bond ability to the existing concrete, Polymer cement mortar is applied in Hand applied Mortar (A) and Mortar (B).

3. Work sequence

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Spalling, Abnormal Anchorage**	**PLATE 3-3**
Remedial Measure	**Hand applied Mortar (A) & (B)**	

Figure 3-3-2 Work sequence



4. Required tools/equipment and material

1) Tools/Equipment

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

- Power Disc Grinder
- Portable Generator
- Brush

2) Material

Hand applied Mortar (A):

- Polymer Cement
- Epoxy Bonding Coat

Hand applied Mortar (B)

- Polymer Cement
- Epoxy Bonding Coat
- Zinc Rich Primer

5. Requirement, Specifications

5-1 Material

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

1) Polymer Cement

MAJOR REPAIR METHODS		
Defect/Deficiency	**Spalling, Abnormal Anchorage**	**PLATE 3-3**
Remedial Measure	**Hand applied Mortar (A) & (B)**	

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

Table 3-3-1 Specifications of Polymer Cement

Property	Test Method	Unit	Specification
Thermal Expansion	ASTM C531	mm/mm℃	2.0×10^{-5}
Slant Shear Bond to Concrete	ASTM C882	N/mm²	1.5 /above
Compressive Strength (7days x 20℃)	ASTM C579	N/mm²	20 /above

2) Corrosion Protective Coating

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

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

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM D695M	N/mm²	75
Flexural Strength	ASTM D790M	N/mm²	40
Tensile Strength	ASTM D638M	N/mm²	30
Tensile Shear Bond to Steel	ASTM D1002	N/mm²	10
Slant Shear Bond to Mortar	ASTM C882	N/mm²	15

3) Zinc Rich Primer

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

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

Property	Test Method	Unit	Specifications
Gloss @ 60° Angle	ASTM D 523	-	Flat
Adhesion	ASTM D 3359	-	Minimum 3A
Salt Spray Resistance	ASTM D3-37	-	Excellent
%Zinc by Weight in Dried Film Test	-	%	87.5±2

5-2 Work requirement

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Spalling, Abnormal Anchorage**	**PLATE 3-3**
Remedial Measure	**Hand applied Mortar (A) & (B)**	

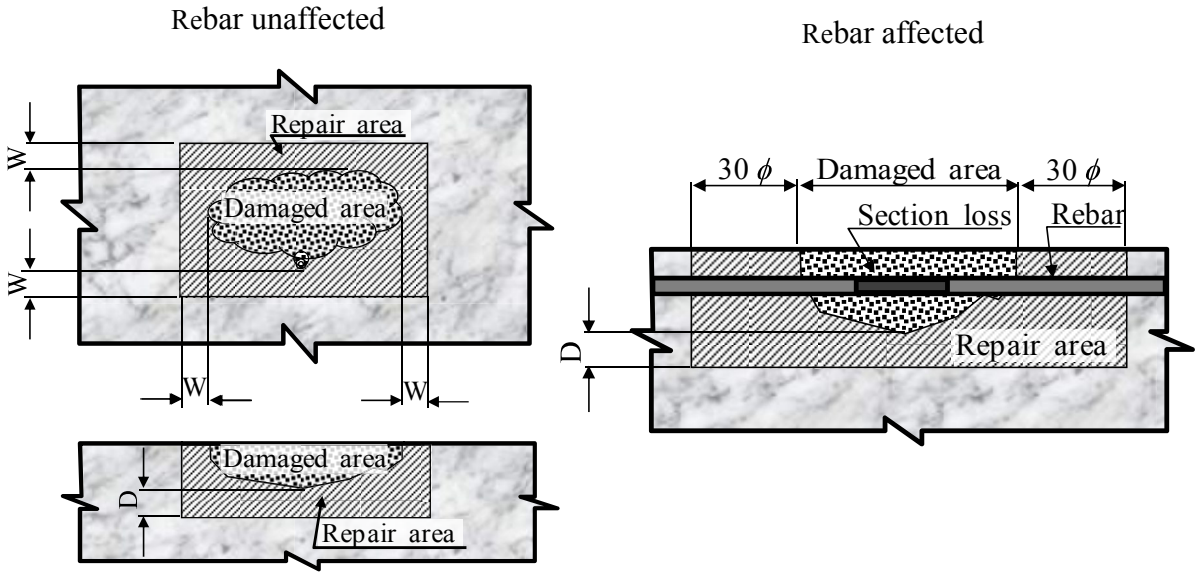
1) Removal of defective concrete

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

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

Removal of defect concrete

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



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

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

2) Cleaning of Concrete and Rebar

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Spalling, Abnormal Anchorage**	**PLATE 3-3**
Remedial Measure	**Hand applied Mortar (A) & (B)**	

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

3) Additional concrete breakout

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

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

4) Additional or replacement rebar

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

5) Bonding coating to concrete and rebar

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

Epoxy bonding coat

6) Filling up repair material

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Spalling, Abnormal Anchorage**	**PLATE 3-3**
Remedial Measure	**Hand applied Mortar (A) & (B)**	

Generally, there should be no time delays between the placing and compacting of layers. The patching to the surrounding concrete is performed using a form material, and then hammered using a mallet, wood float or steel trowel.

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

Filling up in Patching

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

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

7) Curing

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

Curing after Patching

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.

MAJOR REPAIR METHODS		
Defect/Deficiency	**Spalling, Abnormal Anchorage**	**PLATE 3-3**
Remedial Measure	**Hand applied Mortar (A) & (B)**	

6. Method of Measurement and Payment

6-1 Method of Measurement

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

6-2 Basis of Payment

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

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Delamination, Spalling**	**PLATE 3-4**
Remedial Measure	**Spray applied mortar**	

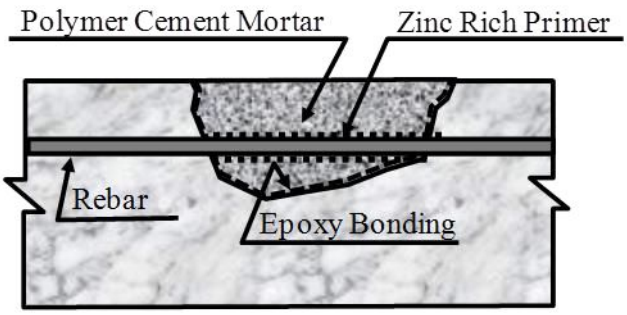
1. Work description

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

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

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

Figure 3-4-1 Spray applied Mortar



2. Application Criteria

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

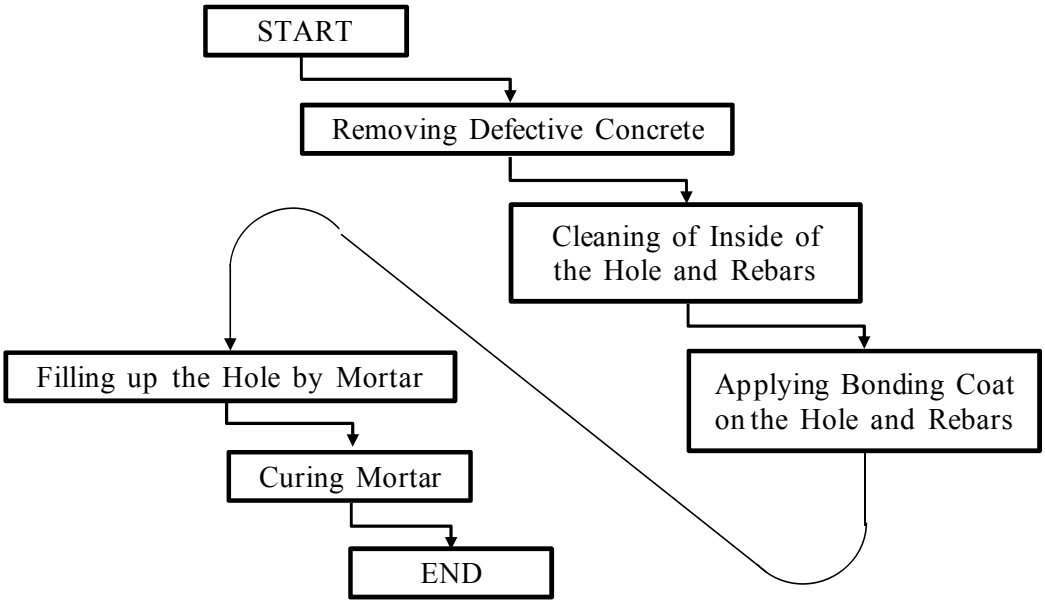
To keep good bond ability to the existing concrete, Polymer cement mortar is applied in Spray applied mortar.

3. Work sequence

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Delamination, Spalling**	**PLATE 3-4**
Remedial Measure	**Spray applied mortar**	

Figure 3-4-2 Work sequence



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

1) Tools/Equipment

Spray applied mortar:

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

2) Material

Spray applied Mortar

- Polymer Cement
- Epoxy Bonding Coat
- Zinc Rich Primer

5. Requirement, Specifications

5-1 Material

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Delamination, Spalling**	**PLATE 3-4**
Remedial Measure	**Spray applied mortar**	

Polymer cement mortar shall conform to the requirements of the specifications shown in Table 3-4-1 or equivalent ASTM Specifications.

Property	Test Method	Unit	Specification
Thermal Expansion	ASTM C531	mm/mm℃	2.0×10^{-5}
Slant Shear Bond to Concrete	ASTM C882	N/mm²	1.5 /above
Compressive Strength (7days x 20℃)	ASTM C579	N/mm²	20 /above

2) Corrosion Protective Coating

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

Property	Test Method	Unit	Specifications
Compressive Strength	ASTM D695M	N/mm²	75
Flexural Strength	ASTM D790M	N/mm²	40
Tensile Strength	ASTM D638M	N/mm²	30
Tensile Shear Bond to Steel	ASTM D1002	N/mm²	10
Slant Shear Bond to Mortar	ASTM C882	N/mm²	15

3) Zinc Rich Primer

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

Property	Test Method	Unit	Specifications
Gloss @ 60° Angle	ASTM D 523	-	Flat
Adhesion	ASTM D 3359	-	Minimum 3A
Salt Spray Resistance	ASTM D3-37	-	Excellent
%Zinc by Weight in Dried Film Test	-	%	87.5±2

5-2 Work requirement

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

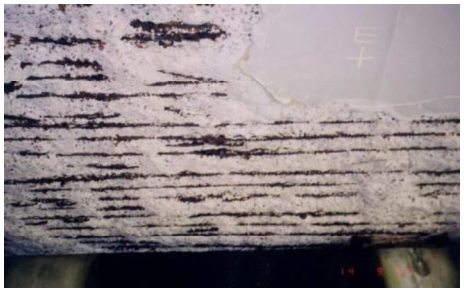
MAJOR REPAIR METHODS		
Defect/Deficiency	**Delamination, Spalling**	**PLATE 3-4**
Remedial Measure	**Spray applied mortar**	

1) Removal of defective concrete

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

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

Removal of defect concrete



Cleaning of Concrete and Rebar

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

2) Cleaning of Concrete and Rebar

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

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Delamination, Spalling**	**PLATE 3-4**
Remedial Measure	**Spray applied mortar**	

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

3) Additional concrete breakout

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

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

4) Additional or replacement rebar

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

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

Additional epoxy coated Rebar

MAJOR REPAIR METHODS		
Defect/Deficiency	**Delamination, Spalling**	**PLATE 3-4**
Remedial Measure	**Spray applied mortar**	

5) Bonding coating to concrete and rebar

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

Epoxy bonding coat

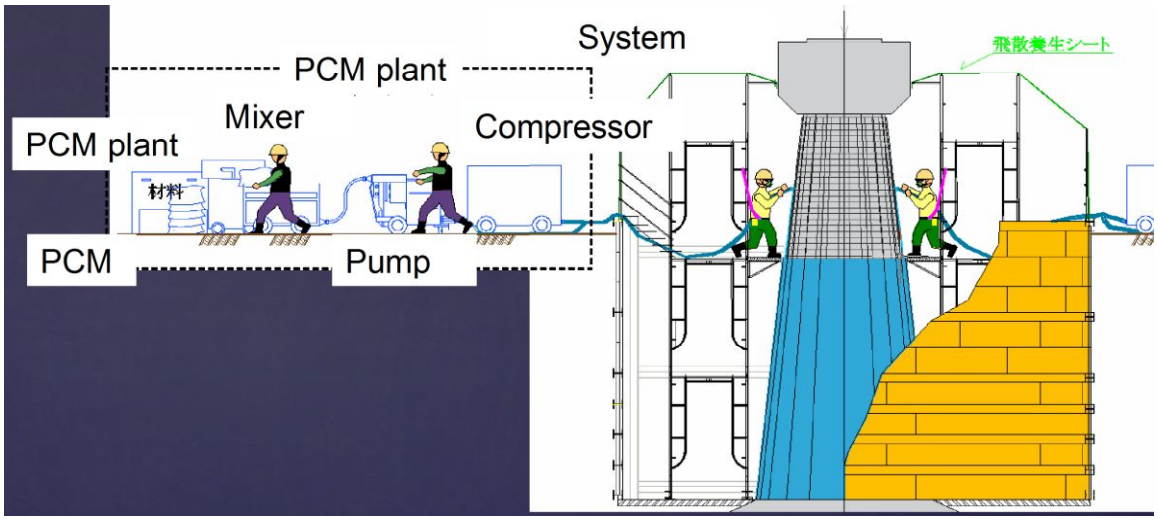
6) Spraying repair material

The spray mortar (Polymer Cement Mortar) should be placed in layers of about 20-40 mm thickness. Spray personal should be trained specialist.

The mortar (PCM) shall be mixed and sprayed using special equipment approved by the Engineer.

Spraying repair mortar

Spraying repair mortar system



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

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

7) Curing

Curing after Spraying

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

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Delamination, Spalling**	**PLATE 3-4**
Remedial Measure	**Spray applied mortar**	

6. Method of Measurement and Payment

6-1 Method of Measurement

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

6-2 Basis of Payment

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

Pay Item No.	Name	Unit of Measurement
3-4	Spray applied Mortar	Square Meter (m^2)

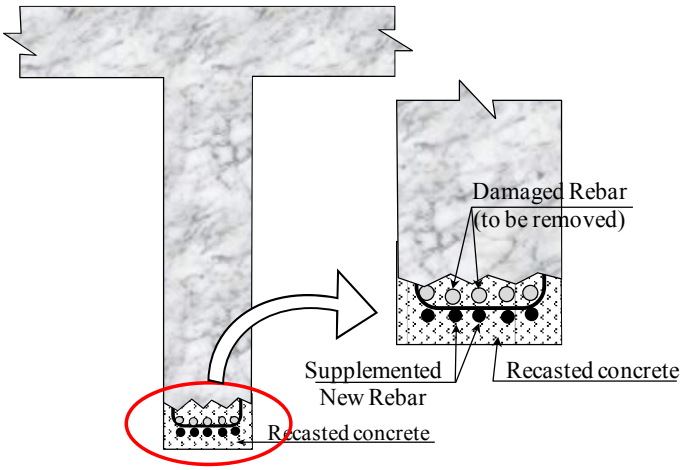
MAJOR REPAIR METHODS		
Defect/Deficiency	**Water Leakage/Efflorescence**	**PLATE 3-5**
Remedial Measure	**Fluid Recasting Mortar/Concrete**	

1. Work description

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

Typical Damage

Figure 3-5-1 Recasting Mortar/Concrete



2. Application Criteria

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

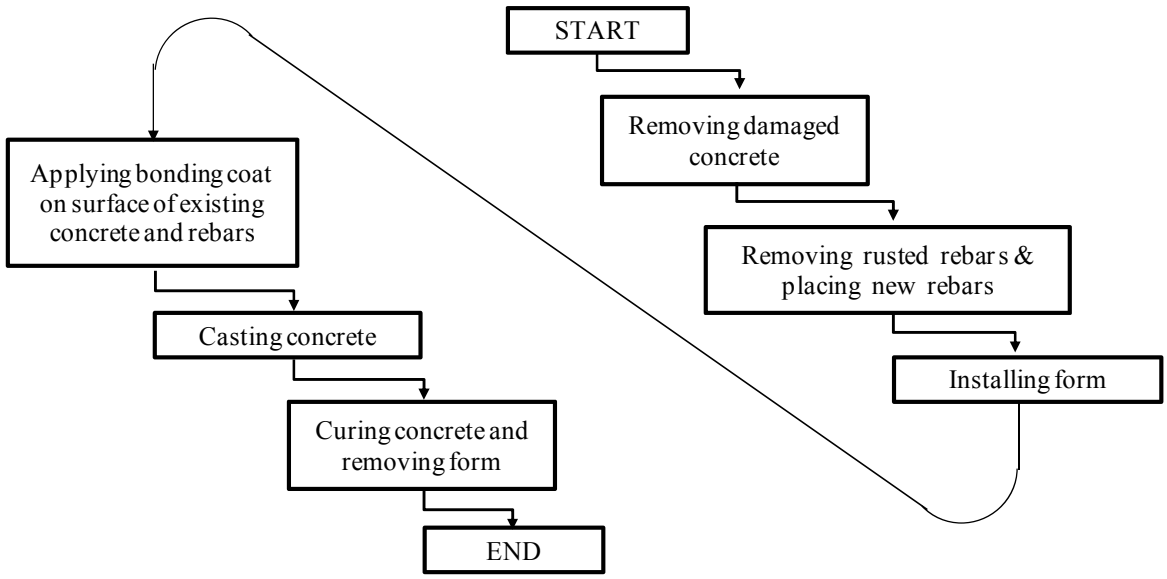
Considering the damaged position, scale of damage, formwork shape and density of rebar, the application of the recasting material such as concrete and grout shall be selected.

3. Work sequence

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Water Leakage/Efflorescence**	**PLATE 3-5**
Remedial Measure	**Fluid Recasting Mortar/Concrete**	

Figure 3-5-2 Work sequence



4. Required Equipment/Tools and Material

4-1 Tools/Equipment

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

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

4-2 Material

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

- For Concrete

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Water Leakage/Efflorescence**	**PLATE 3-5**
Remedial Measure	**Fluid Recasting Mortar/Concrete**	

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

5. Requirement, Specifications

5-1 Material

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

1) Concrete mixture

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

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

2) Epoxy bonding primer

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

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

3) Zinc rich primer

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

Table 3-5-2 Specifications for Zinc Rich Primer

Property	Test Method	Unit	Specifications
Gloss @ 60° Angle	ASTM D 523	-	Flat
Adhesion	ASTM D 3359	-	Minimum 3A
Salt Spray Resistance	ASTM D3-37	-	Excellent
%Zinc by Weight in Dried Film Test		%	87.5±2

5-2 Work requirement

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

1) Removal of damaged concrete

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

2) Removing rusted rebar and supplying new rebar

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

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

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

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Water Leakage/Efflorescence**	**PLATE 3-5**
Remedial Measure	**Fluid Recasting Mortar/Concrete**	

When replacement of rebar is required, followings shall be taken into consideration:

a) Necessity of scaffoldings

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

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

b) Installation of the scaffoldings

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

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

3) Application of bonding coat

The concrete surface to which the bonding coat is to be applied shall be wet using potable water to achieve a moisture condition such that the concrete will not absorb moisture from the mortar. The wetting period will depend upon the substrata condition and the bonding coat manufacturer's recommendations, subject to Engineer's satisfaction.

The surface shall then be left wet until the free water has evaporated before the bonding coat is applied. Using a brush, the coat shall be applied to the exposed concrete surface and exposed concrete reinforcement. The subsequent coat shall be applied while the previous bond coat is still wet or tacky.

MAJOR REPAIR METHODS		
Defect/Deficiency	**Water Leakage/Efflorescence**	**PLATE 3-5**
Remedial Measure	**Fluid Recasting Mortar/Concrete**	

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

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

4) Installation of formwork

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

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

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

5) Mixing and casting mortar/concrete

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

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

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

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

6) Curing and protection

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

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

7) Field Test

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

6. Measurement and Payment

6-1 Method of Measurement

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

6-2 Basis of Payment

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

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

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

Figure 3-5-3 Example of the scaffolding structure

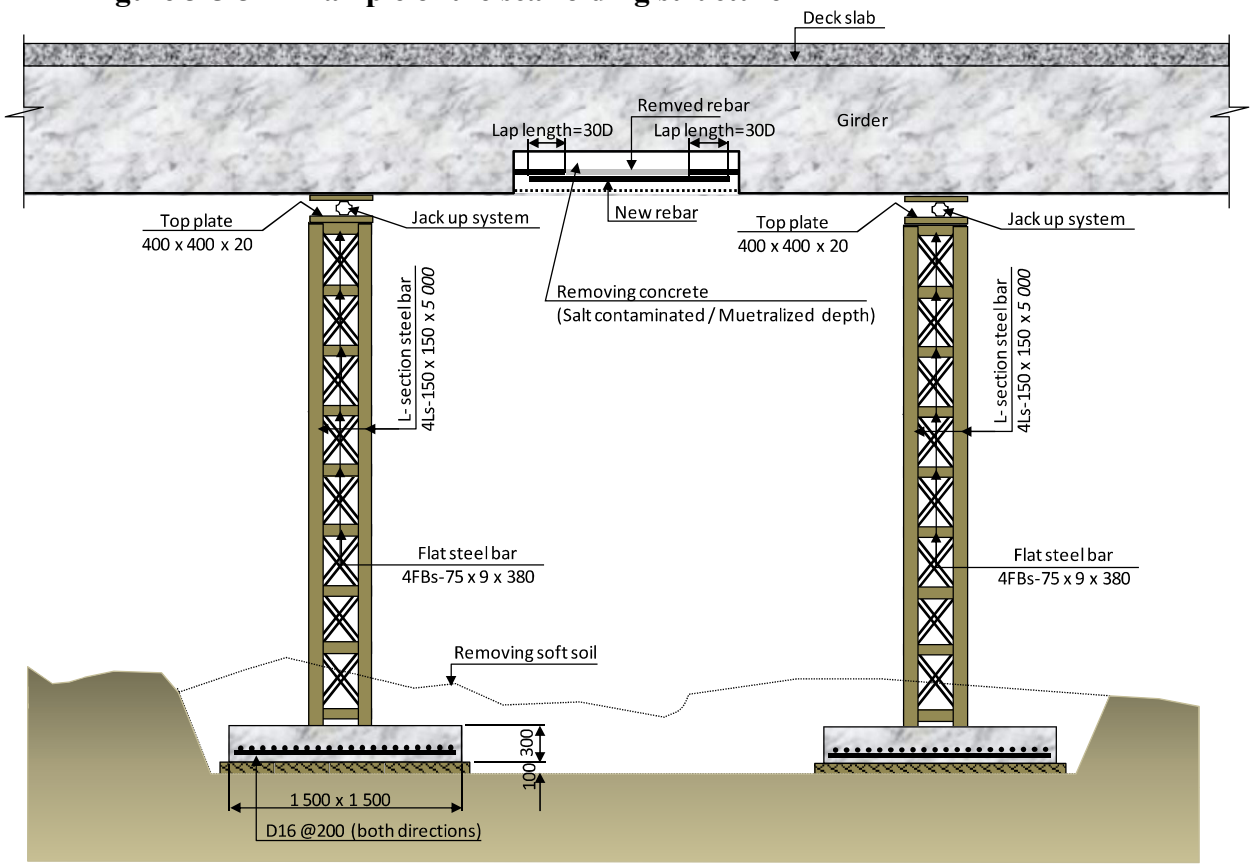
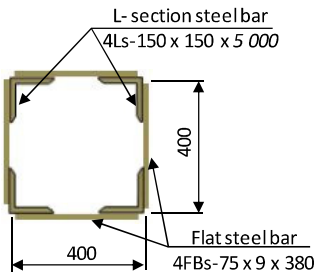


Figure 3-5-4 Cross section of the scaffolding structure



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

1. Work description

Protective coating is the simplest and most effective preventive maintenance in the coastal region against chloride attack. It is recommended to take flexible epoxy-based coating suitable for active cracks and those subject to movement due to applied loads and temperature changes.

The purpose of the Epoxy coating is to prevent water from reaching the reinforcing steel, development of hydrostatic pressure within the crack, staining of concrete surface and causing moisture problems on the far side of the crack.

Epoxy coating is suitable for 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.

2. Application criteria

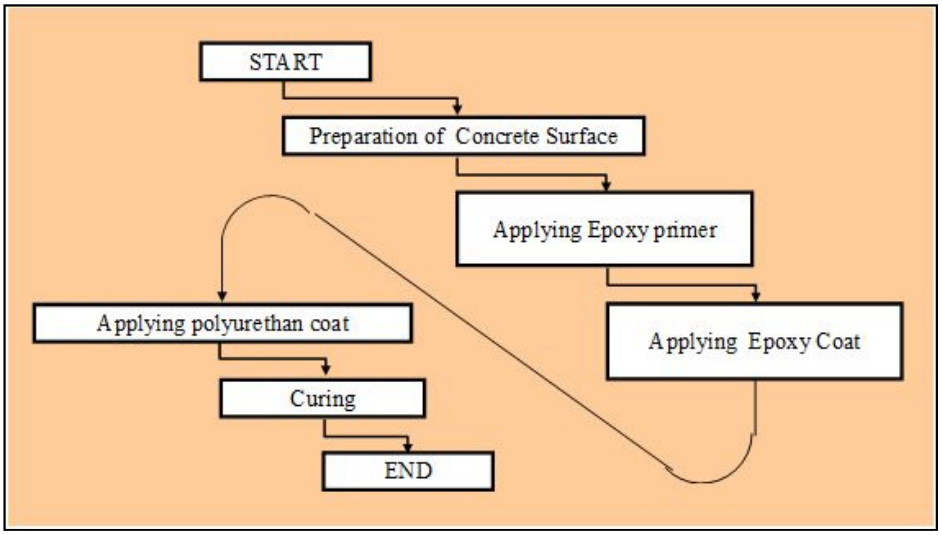
As a protective or preventive measure, epoxy coating should be applied on surfaces of concrete structures, with cracks of less than 0.3 mm width, regardless of whether a crack formation is structural or non-structural. Subsequently, the district office should regularly monitor the cracks for future repair, if necessary.

3. Work sequence

Work sequence of Protective Coating is as shown Figure 3-6-1.

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

Figure 3-6-1 Work sequence



4. Required Equipment/Tool and Material

4.1 Equipment/Tool

Following equipment/tool is necessary for Protective Coating:

- Paint brush or Paint roller

4.2 Material

- Epoxy Plimer and Epoxy Coat
- Polyurethan Coat

5. Requirement, Specification

5-1 Material

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

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

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

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

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

5-2 Work requirement

1) Preparation of Concrete Surface

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

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

2) Application of protective coating

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

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

Items	**Thickness**	**Usage kg/m2**		**remark**
Epoxy primer		0.1	brush,roller	over 16 hour
Epoxy putty		0.5	brush,roller	over 16 hour
flexible Epoxy coat	160 μm	0.35	brush,roller	over 16 hour
flexible polyurethan coat	30μm	0.12	brush,roller	

The epoxy putty is used for leveling of concrete surface.

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

3) Curing

After application, perform until the protective coating hardens.

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

6. Measurement and Payment

6-1 Method of Measurement

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

6-2 Basis of Payment

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

Pay Item No.	Name	Unit of Measurement
3-6	Protective Coating	Square Meter (m^2)

MAJOR REPAIR METHODS		
Defect/Deficiency	**Fallen out of Deck slab**	**PLATE 3-7**
Remedial Measure	**Partial Replacement of Deck slab**	

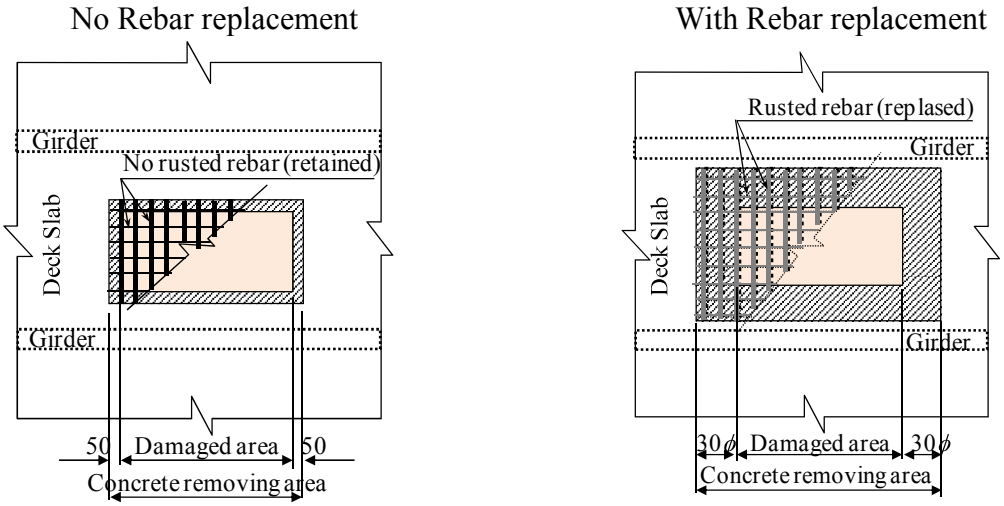
1. Work description

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

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

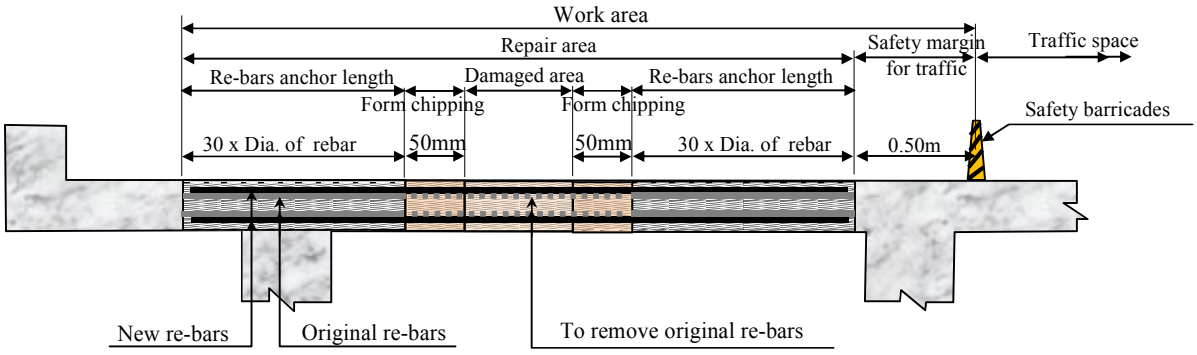
Damaged Deck Slab with water leakage

Figure 3-7-1 Partial Replacement of Deck Slab



MAJOR REPAIR METHODS		
Defect/Deficiency	**Fallen out of Deck slab**	**PLATE 3-7**
Remedial Measure	**Partial Replacement of Deck slab**	

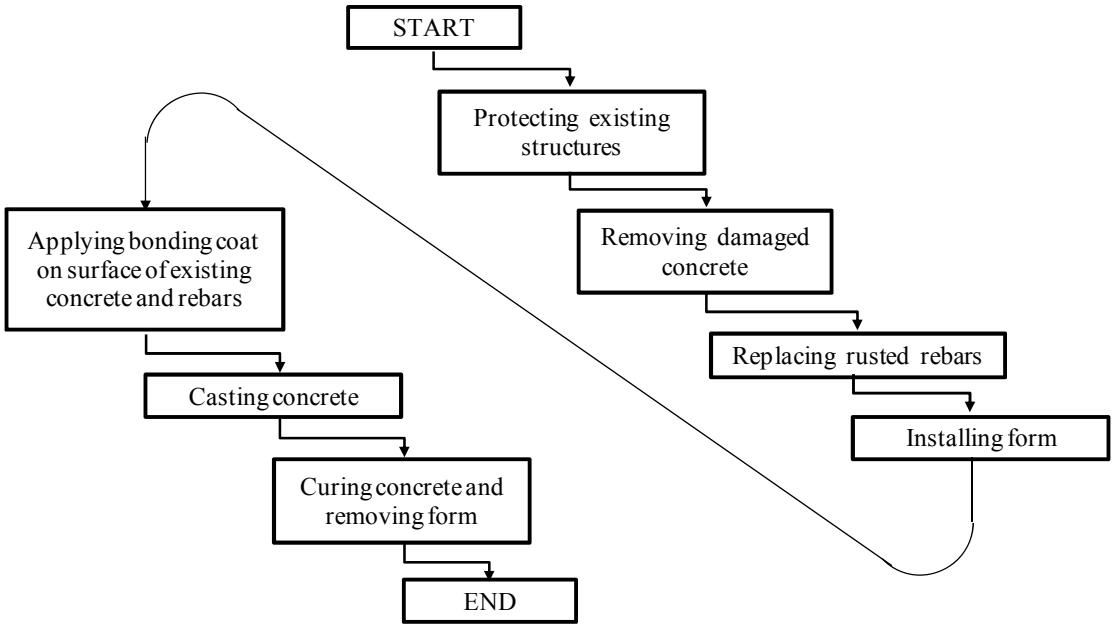
Figure 3-7-2 Partial Replacement of Concrete with Rebar Replacement



2. Work sequence

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

Figure 3-7-3 Work sequence



3. Required Equipment/Tool and Material

3-1 Equipment/Tool

Following Equipment/Tool are necessary for the work.

-Sawing equipment

MAJOR REPAIR METHODS		
Defect/Deficiency	**Fallen out of Deck slab**	**PLATE 3-7**
Remedial Measure	**Partial Replacement of Deck slab**	

-High pressure water blasting
-Handy concrete breaker or jack hammer
-Handy power chisel
-Concrete mixer 30 liters
-Vibrator
-Troweling tools

3-2 Materials

-Portland cement
-Silica fume
-Rebar
-Epoxy Resin (Bonding coat to concrete)
-Zinc rich primer (Bonding coat to rebar)

4. Requirement, Specification

4-1 Work requirement

The Contractor shall submit the Methodology (procedures) of the Work to the Engineer for his review and approval before the work commences.

1) Protection of existing structure

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

2) Removal of concrete

All deteriorated or damaged concrete surfaces are cut by saw, forming vertical edges, and then removed using breaker and chisel. Rebars are examined for loss of section due to corrosion. If cross sectional area of the reinforcement has reduced by more than 20%, additional reinforcement is required and necessary.

Concrete areas subjected for full-depth repair shall be removed, as determined by the Engineer. While, for partial depth repair it, should extend below half the concrete deck thickness. Saw cuts shall be made on the perimeter of the deck to be replaced. Concrete saw shall then be used to form vertical edges, with approximately 20 mm deep, around the defined perimeter. Deck slab concrete is removed using a breaker while hand power chisel is used near the vertical edges.

MAJOR REPAIR METHODS		
Defect/Deficiency	**Fallen out of Deck slab**	**PLATE 3-7**
Remedial Measure	**Partial Replacement of Deck slab**	

3) Rebar replacement

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

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

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

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

4) Installation of form

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

5) Application of bonding coat

The concrete surface to which the bond coat is to be applied shall be wet using potable water to achieve a moisture condition such that the concrete will not absorb moisture from the repair mortar. The wetting period will depend upon the substrata condition and the bond coat manufacturer's recommendations, subject to Engineer's satisfaction.

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

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

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

6) Mixing concrete

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

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

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

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

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

- Cement

  -Portland cement 13.0 kg

  -Silica fume 0.5 kg (If silica fume is unavailable, use 13.5kg cement)

- 10mm Crushed Aggregate 36.0 kg
- Sand (assumed with 2% water content) 18.5 kg
- Water (maximum) 5.4 liters
- Super plasticizer (nominal) 25ml

7) Casting concrete

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

5. Measurement and Payment

5-1 Method of measurement

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

5-2 Basis of payment

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

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

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

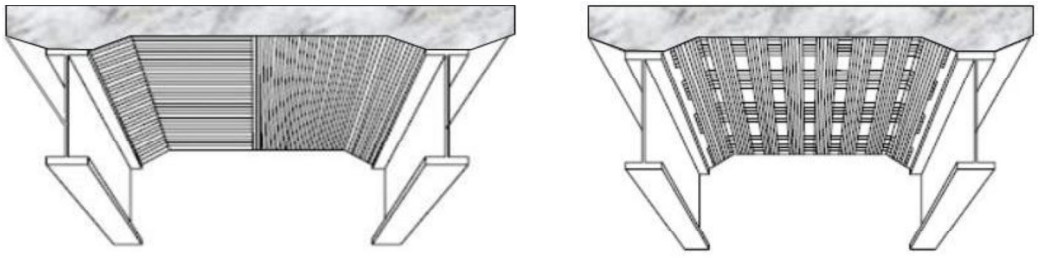
1. Work description

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

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

Figure 3-8-1 Arrangement of Carbon Fiber Sheet

Continuous Arrangement **Grid Arrangement**



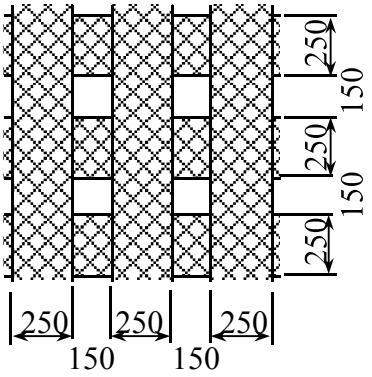
2. Application Criteria

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

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

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

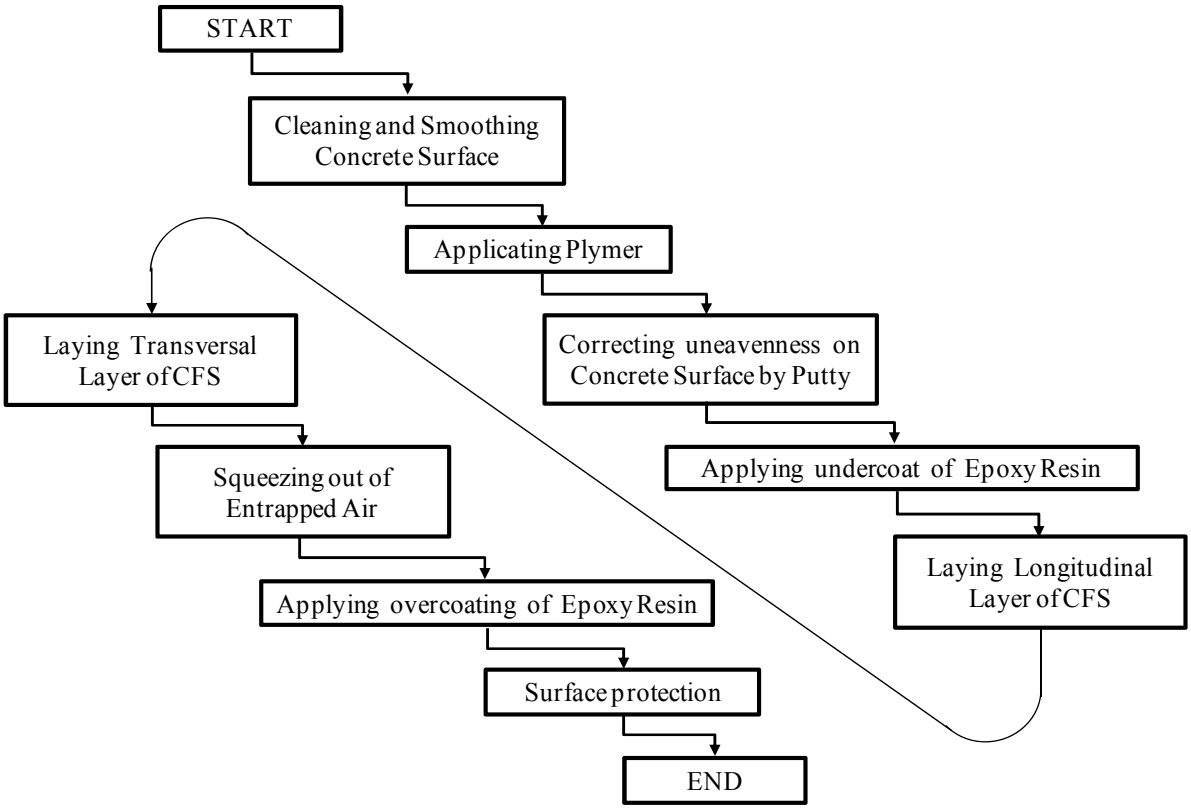
Figure 3-8-2 Carbon Fiber Sheet Arrangement



3. Work sequence

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

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



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

4. Required Equipment/Tool and Material

1) Equipment/Tools

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

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

2) Material

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

Carbon Fiber Products
-CFS (Strap Type)

Epoxy Materials
-Epoxy primer
-Epoxy putty
-Epoxy resin adhesive

5. Requirement, Specifications

5-1 Material

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

1) Carbon Fiber Sheet (CFS)

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

Table 3-8-1 Specification of CFS

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

2) Epoxy Resin Adhesive

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

Table 3-8-2 Specification of Epoxy Resin Adhesive

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

5-2 Work Requirement

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

1) Surface preparation

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

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

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

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

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

2) Application of Primer

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

Contact surface shall be dry before coating with primer.

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

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

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

3) Adjustment of Unevenness with Putty

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

The application method is as follows:

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

4) Application of Epoxy Resin for Undercoat

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

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

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

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,, 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 a rate of 0.5 kg/sq.m,

5) Putting Longitudinal Layer of 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.

The ideal length of carbon sheet is the full length of the slab. It should be avoid wrinkles with adequate caution.

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

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

6) Putting Transverse Layer of CFS

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

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

7) Squeezing of Strip to Entrapped Air

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

8) Over-Coat Application using Epoxy Resin

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

9) Surface Protection

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

10) Quality Control and Inspection

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

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

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

- ✓ 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.

6. Measurement and Payment

6-1 Method of Measurement

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

6-2 Basis of Payment

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

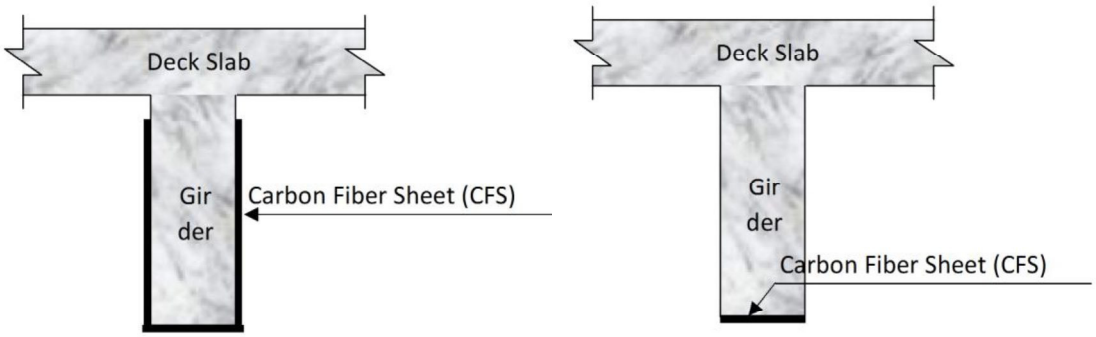
Pay Item No.	Name	Unit of Measurement
3-8	Carbon Fiber Sheet Bonding (Deck slab)	Square Meter (m^2)

MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack on Concrete (Girder)**	**PLATE 3 - 9**
Remedial Measure	**Carbon Fiber Sheet Bonding**	

1. Work description

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

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

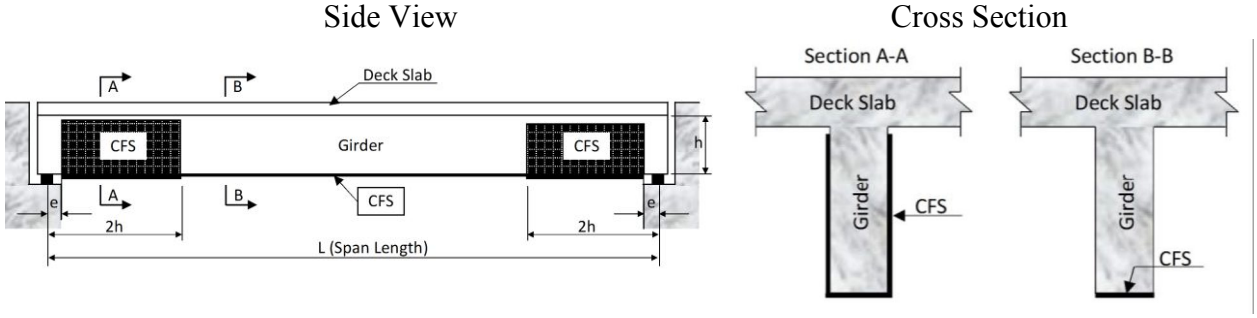


2. Application Criteria

The Carbon Fiber Sheet (CFS) system for concrete girder generally consists of woven CFS reinforcing layers bonded to the concrete surface with epoxy.

As shown in Figure 3-9-2, the section of 2h in span from both ends (A-A) is applied with U-formed CFS as protection against shear cracks (Photo 9-1) while the full span length (B-B) is applied with first CFS layer for protection against flexural cracks (Photo 9-2) caused by live load. For practical reason, along both edge distances (e) let free of CFS.

Figure 3-9-2 Typical application method of CFS



MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack on Concrete (Girder)**	**PLATE 3 - 9**
Remedial Measure	**Carbon Fiber Sheet Bonding**	

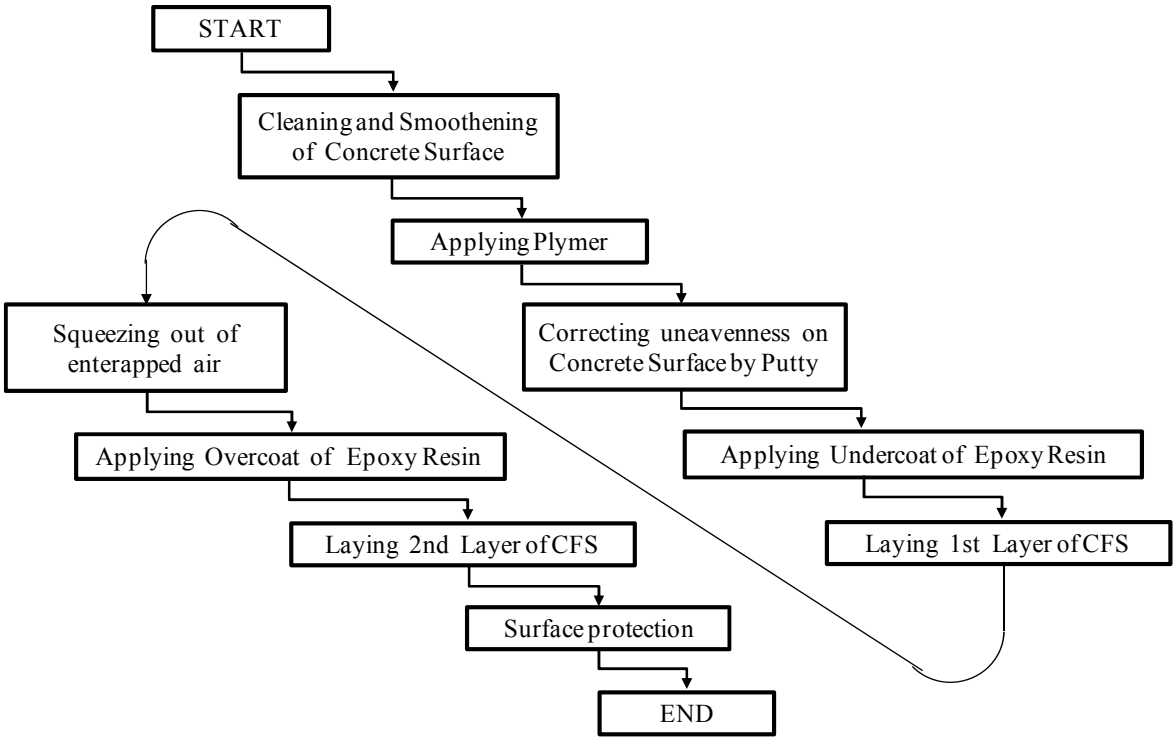
Photo 9-1 Example of Shear Crack

Photo 9-2 Example of Flexural Crack

3. Work sequence

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

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



MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack on Concrete (Girder)**	**PLATE 3 - 9**
Remedial Measure	**Carbon Fiber Sheet Bonding**	

4. Required Equipment/Tool and Material

1) Equipment/Tools

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

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

2) Materials

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

Carbon Fiber Products
-CFS (longitudinal) for bending strengthening
-CFS (vertical) for shear strengthening

Epoxy Materials
-Epoxy primer
-Epoxy putty
-Epoxy resin adhesive

5. Requirement, Specifications

5-1 Material

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

1) Carbon Fiber Sheet (CFS)

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

Table 3-9-1 Specification of CFS

Property	Specifications	Test method
Fiber Areal Weight	300 g/m^2 above	ISO 18319
Design thickness	0.163 mm	ISO 18319
Tensile strength	2400 N/mm^2 above	ISO 10406-2
Tensile bond to concrete	1.5 N/mm^2 above	ISO 10406-2
Young's modulus	(4.40±0.44) x10^5 N/mm^2	ISO 10406-2

2) Epoxy Resin Adhesive

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

Table 3-9-2 Specification of Epoxy Resin Adhesive

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

5-2 Work Requirement

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

1) Surface preparation

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

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack on Concrete (Girder)**	**PLATE 3 - 9**
Remedial Measure	**Carbon Fiber Sheet Bonding**	

2) Material handling

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

3) Application of Primer

Primer resin soaks into the surface of concrete, resulting in increased strength of the concrete surface and improved bonding with CFS. Contact surface shall be dry before coating with primer. The primer should be formulated and compatible with the carbon fiber material and not to be applied during rains, storms or when the air is misty or when conditions are unsatisfactory in the opinion of the Engineer.

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

4) Adjustment of Unevenness with Putty

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

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

The application method is as follows:

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

5) Application of Epoxy Resin for Undercoat

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack on Concrete (Girder)**	**PLATE 3 - 9**
Remedial Measure	**Carbon Fiber Sheet Bonding**	

The contractor shall check and confirm that the primer and putty have become tack-free and there is no clay and dust on the concrete surface prior to Engineer's Inspection.

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

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

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

6) Putting 1st Layer of CFS (longitudinal)

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

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

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

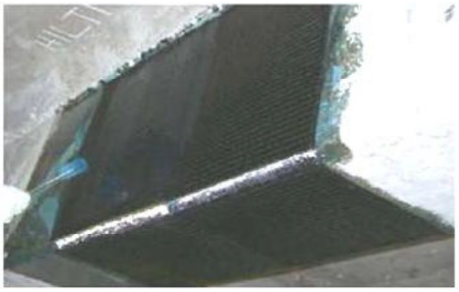
- ✓ Stick the CFS in the longitudinal direction with a reasonable lapse of 20 to 30 minutes after the epoxy resin application,
- ✓ Press the CFS using a roller (plastic roller is preferred) starting from the center towards the edge to squeeze out entrapped air before the epoxy resin sets.
- ✓ When lapping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

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

7) Squeezing out Entrapped Air

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

8) Overcoat Application using Epoxy Resin



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

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

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

9) Putting 2nd Layer of CFS

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

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

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

Surface Protection

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

10) Quality Control and Inspection

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

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

11) Testing

After allowing at least 24 hours for initial resin saturate to cure, the Contractor shall perform a visual and acoustic tap test inspection of the layered surface. All voids, bubbles and delaminations shall be repaired in accordance with manufacturer's recommendations. The Contractor shall conduct adhesion testing of the fully cured CFS and assembly using direct pull-off tests, at locations determined by the Engineer. Failure at the bond line at tensile stress below 14kgf/cm^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.

6. Measurement and Payment

6-1 Method of Measurement

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

6-2 Basis of Payment

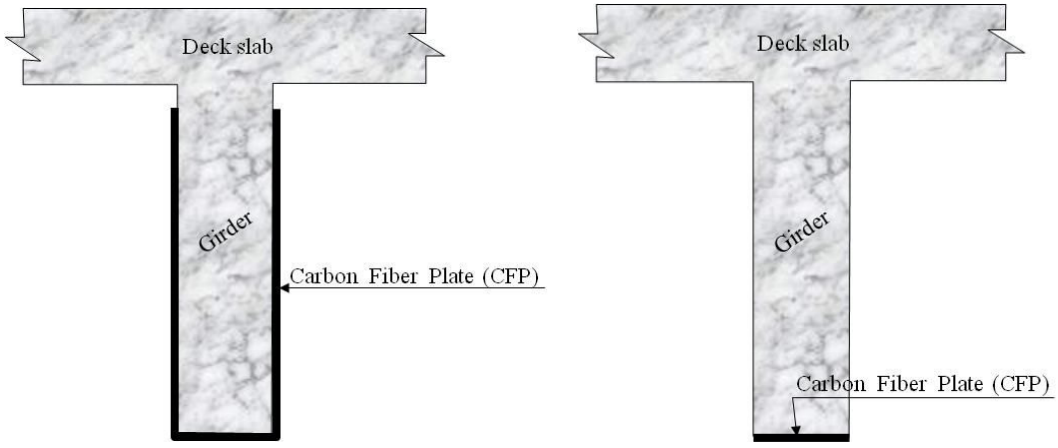
The quantity, measured as prescribed above, shall be paid for at a contract unit price. Epoxy injection of cracks will not be paid for directly and is considered subsidiary to the works. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related services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

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack on Concrete (Girder)**	**PLATE 3 - 10**
Remedial Measure	**Carbon Fiber Plate Bonding**	

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

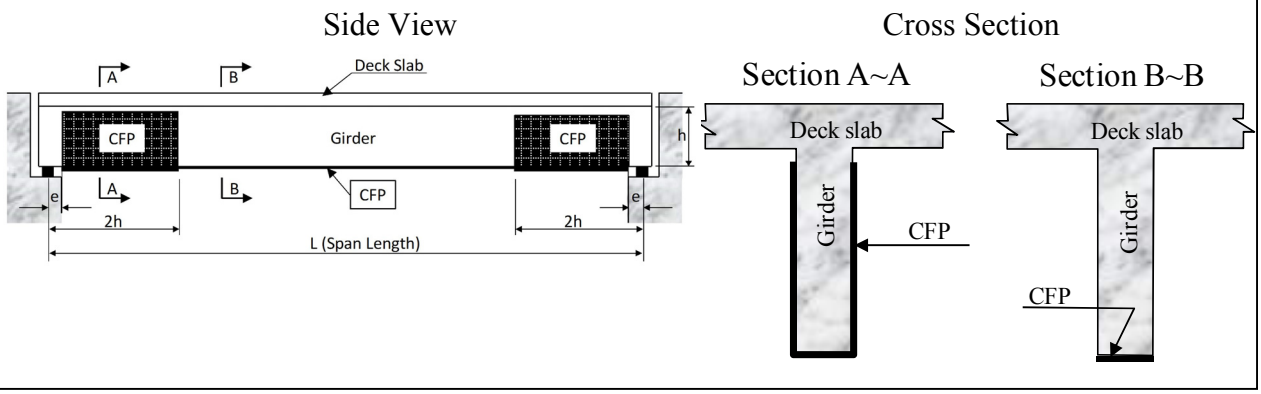
Figure 3-10-1 Reinforcing Girder by Carbon Fiber Plate



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

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

Figure 3-10-2 Typical application method of CFP



MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack on Concrete (Girder)**	**PLATE 3 - 10**
Remedial Measure	**Carbon Fiber Plate Bonding**	

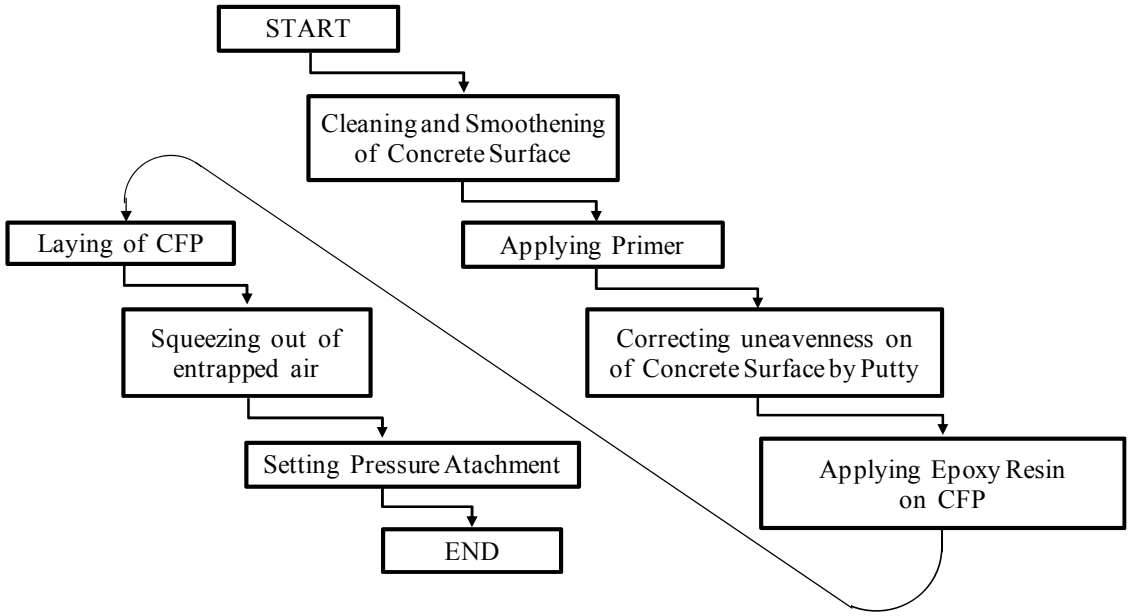
Photo 10-1 Example of Shear Crack

Photo 10-2 Example of Flexural Crack

2. Work sequence

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

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



3. Required Equipment/Tool and Material

1) Equipment/Tool

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

-Abrasive Sandblaster

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

2) Material

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

Carbon Fiber Products
-CFP (longitudinal)
-CFP (vertical)

Epoxy Materials
-Epoxy primer
-Epoxy putty
-Epoxy resin adhesive

5. Requirement, Specifications

5-1 Material

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

1) Carbon Fiber Plate (CFP)

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

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

Table 3-10-1 Specification of CFP

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

2) Epoxy Resin Adhesive

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

Table 3-10-2 Specification of Epoxy Resin Adhesive

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

5-2 Work Requirement

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

1) Surface preparation

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

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

2) Material handling

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

in conformity with the manufacturer's recommendations and instructions.

3) Application of Primer

Primer resin soaks into the surface of concrete, resulting in increased strength of the concrete surface and improved bonding with CFP. Contact surface shall be dry before coating with primer. The primer should be formulated and compatible with the carbon fiber material and shall not be applied during rains, storms or when the air is misty or when conditions are unsatisfactory in the opinion of the Engineer.

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

4) Adjustment of Unevenness with Putty

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

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

The application method is as follows:

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

5) Application of Epoxy Resin on CFP

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

The Contractor shall submit for the Engineer's

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

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

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

6) Putting CFP

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

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

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

- ✓ CFP may be used at surfaces where some abrasion is required as per manufacturer's recommendations, provided that the plates are manufactured according to the required roughness.
- ✓ Apply the adhesive on the surface at the rate of 0.4 ~ 0.5 kg/m^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) Squeezing of Strip to Entrapped Air

For complete impregnation, entrapped air is

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

8) Setting Pressure Attachment

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

9) Quality Control and Inspection

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

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

10) Testing

After allowing at least 24 hours for initial resin saturate to cure, the Contractor shall perform a visual and acoustic tap test inspection of the layered surface. All voids, bubbles and delaminations shall be repaired in accordance with manufacturer's recommendations. The Contractor shall conduct adhesion testing of the fully cured CFP and assembly using direct pull-off tests, at locations determined by the Engineer. Failure at the bond line at tensile stress below 14kgf/cm^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 CFP.

6. Measurement and Payment

6-1 Method of Measurement

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack on Concrete (Girder)**	**PLATE 3 - 10**
Remedial Measure	**Carbon Fiber Plate Bonding**	

6-2 Basis of Payment

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

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack in Steel Girder**	**PLATE 3 - 11**
Remedial Measure	**Supplementing Steel Plate**	

1. Work description

Defects of a steel structure will be categorized as (i) Rusting/Corrosion, (ii) Crack/Breakage, (iii) Deformation, (iv) Losing/Missing bolts, etc.
Causes of above defects of the steel structure will be (i) Lack of maintenance of painting, (ii) Over stress due to heavy traffic, (iii) Vibration caused by traffic, (iv) Fatigue, (v) Lack of consideration of a detailed structural design, etc.

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

2. Application criteria

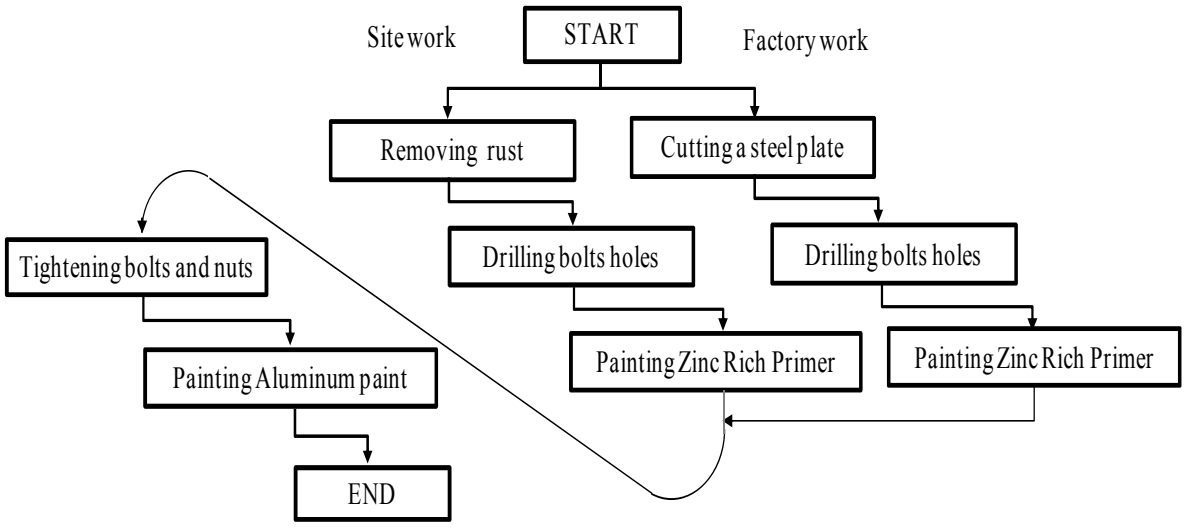
Supplemental steel plate without replacement of a member will be applicable to Crack/breakage of the member.

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

3. Work sequence

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

Figure 3-11-1 Work sequence



4. Required Equipment/Tool and Material

4-1 Equipment/Tool

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

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

4-2 Material

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

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

5. Requirement, Specification

5-1 Material

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

1) Steel material

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

2) Zinc rich primer

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

Table 3-12-1 Specifications of Zinc rich primer

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

3) Aluminum paint

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

Table 3-11-2 Specification of Aluminum paint

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

5-2 Work requirement

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

1) Preparation in a factory

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

Thickness of Zinc rich primer of each layer is 75μm and minimum time interval of works is 8 hours.

Before

2) Preparation on the site

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

Removing rust on the member to be repair

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

After Supplementing Plate

3) Drilling bolt holes

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

4) Painting Zinc rich primer

Zinc rich primer of 2 layers shall be applied on surfaces of the member. Thickness of Zinc rich primer of each layer is 75μm and minimum time interval of works is 8 hours.

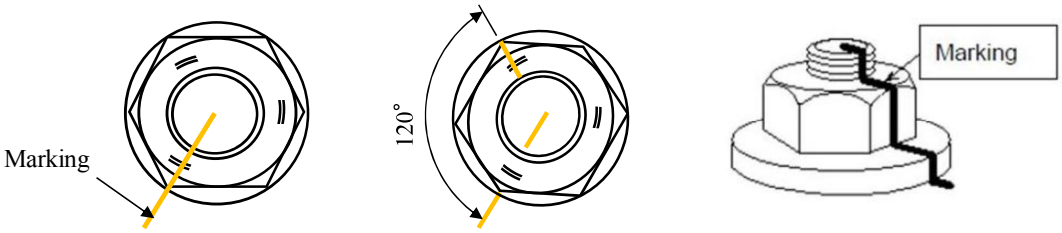
5) Applying the steel plate and tightening HTB

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

Tightening of HTB will be carried out with 2 steps.

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

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



6) Painting top layer by Aluminum paint

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

Thickness of Aluminum paint of each layer is 50μm and minimum time interval of works is 4 hours.

The paint shall be applied widely around the supplement plates.

6. Measurement and Payment

6-1 Method of measurement

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack of Steel Pier**	**PLATE 3 - 11**
Remedial Measure	**Supplementing Steel Plate**	

6.2 Basis of Payment

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

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack of Steel Pier**	**PLATE 3 - 12**
Remedial Measure	**Supplementing Steel Plate**	

1. Work description

Defects of a steel structure will be categorized as (i) Rusting/Corrosion, (ii) Crack/Breakage, (iii) Deformation, (iv) Losing/Missing bolts, etc.
Causes of above defects of the steel structure will be (i) Lack of maintenance of painting, (ii) Over stress due to heavy traffic, (iii) Vibration caused by traffic, (iv) Fatigue, (v) Lack of consideration of a detailed structural design, etc.

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

2. Application criteria

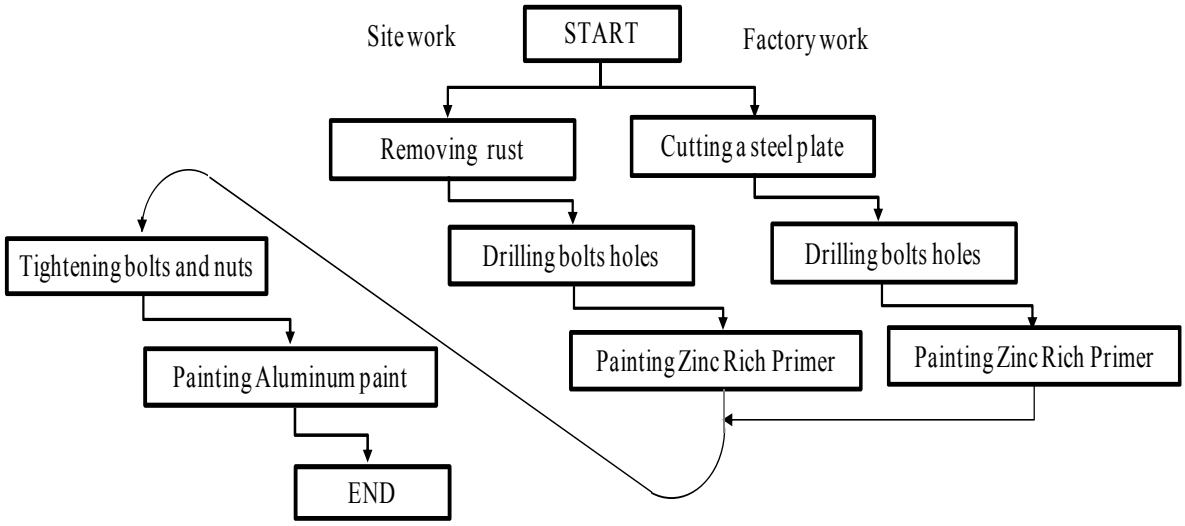
Supplemental steel plate without replacement of a member will be applicable to Crack/breakage of the member.

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

3. Work sequence

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

Figure 3-12-1 Work sequence



4. Required Equipment/Tool and Material

4-1 Equipment/Tool

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

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

4-2 Material

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

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

5. Requirement, Specification

5-1 Material

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

1) Steel material

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

2) Zinc rich primer

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

Table 3-12-1 Specifications of Zinc rich primer

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

3) Aluminum paint

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

Table 3-12-2 Specification of Aluminum paint

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

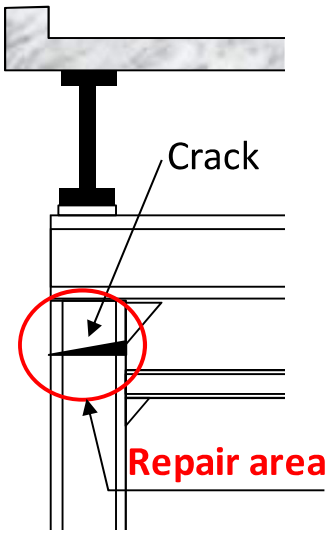
5-2 Work requirement

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

1) Preparation in a factory

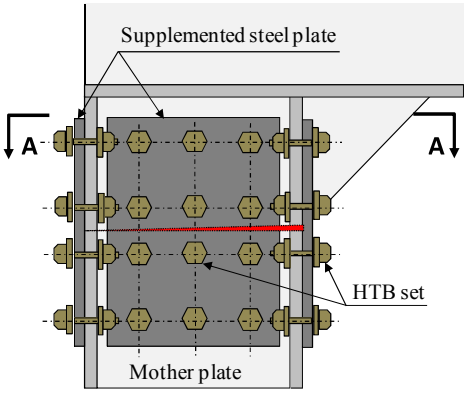
Supplemental steel plates will be prepared in the factory where the steel plates are cut based on measured size and then drilled necessary number of bolts holes. Zinc rich primer of 2 layers shall be applied on all surfaces of the steel plates.

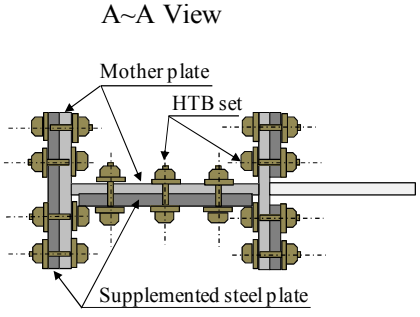
Thickness of Zinc rich primer of each layer is 75μm and minimum time interval of works is 8 hours.



2) Preparation on the site

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





MAJOR REPAIR METHODS		
Defect/Deficiency	**Crack of Steel Pier**	**PLATE 3 - 12**
Remedial Measure	**Supplementing Steel Plate**	

Removing rust on the member to be repair

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

3) Drilling bolt holes

Bolt holes are drilled on the member based on drawings.

4) Painting Zinc rich primer

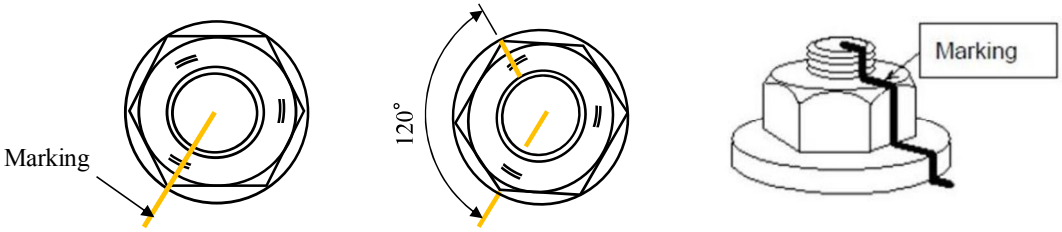
Zinc rich primer of 2 layers shall be applied on surfaces of the member. Thickness of Zinc rich primer of each layer is 75μm and minimum time interval of works is 8 hours.

5) Applying the steel plate and tightening HTB

Tightening of HTB will be carried out with 2 steps.

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

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



6) Painting top layer by Aluminum paint

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

Thickness of Aluminum paint of each layer is 50μm and minimum time interval of works is 4 hours.

6. Measurement and Payment

6-1 Method of measurement

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

6.2 Basis of Payment

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

equipment, tools. It shall also include construction and removal of scaffoldings and other temporary works necessary to complete the Supplementing steel plate.

Pay Item No.	Name	Unit of Measurement
3-12	Supplementing Steel Plate	Kilogram (Kg)

MAJOR REPAIR METHODS		
Defect/Deficiency	**Spalling/Exposed Rebar of Bored Pile**	**PLATE 3 - 13**
Remedial Measure	**Filling pile mortar/concrete**	

1. Work description

Due to scouring some of bored pile head areas below a pile cap appear above ground surface with spalling cover concrete/missing concrete section and exposing rebar. Main cause of spalling can be supposed as lack of pile head treatment length, meanwhile, missing concrete section can be supposed as wrong measurement of the pile top elevation.

Patching repair of bored concrete pile is performed to restore small areas where sound concrete is damaged by spalling, scaling and impact. This method of repair is generally applied using trowel and require none or minimum formworks.

The other hand, Filling pile concrete is performed to restore missing concrete section of the bored pile where concrete of the section missed due to wrong measurement of the pile top elevation..

Photo 13-1 Missing concrete and Exposed rebar

2. Application criteria

Patching of pile concrete is applicable to the piles whose concrete spalling with rebar exposure. Patching of pile concrete applies to polymer cement mortar.

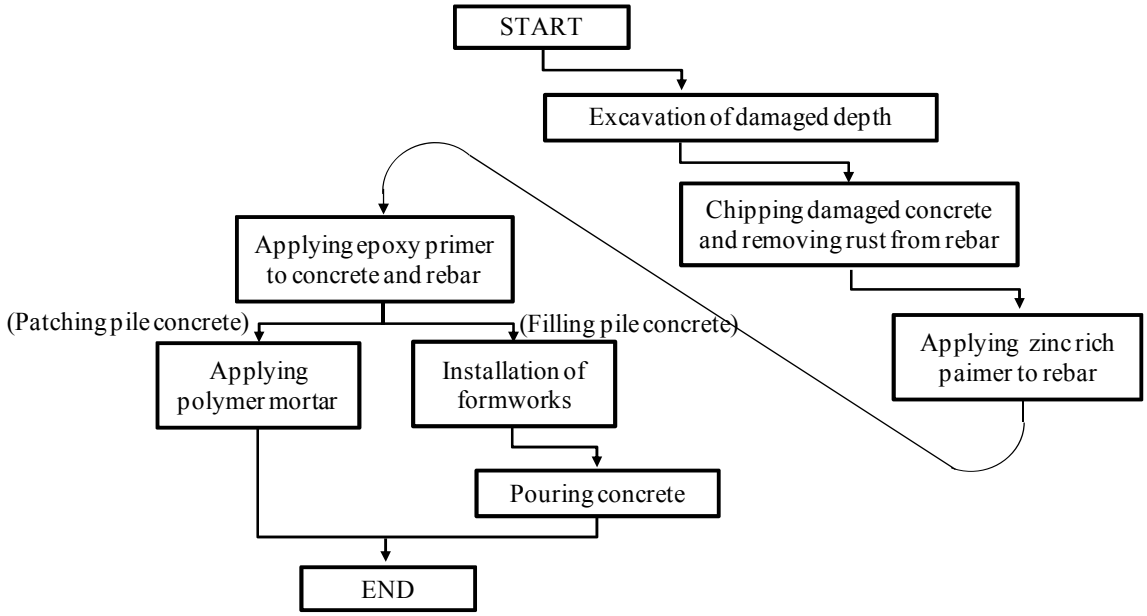
Filling pile concrete is applicable to the pile which has missing section of concrete with rebar exposure. Filled concrete is Portland cement.

3. Work sequence

Work sequence of replacement method of Patching/Filling pile concrete is as shown in Figure 3-13-1.

MAJOR REPAIR METHODS		
Defect/Deficiency	**Spalling/Exposed Rebar of Bored Pile**	**PLATE 3 - 13**
Remedial Measure	**Filling pile mortar/concrete**	

Figure 3-13-1 Work sequence



4. Required Equipment/Tool and Material

4-1 Equipment/Tool

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

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

4-2 Material

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

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

5. Requirement, Specification

5-1 Material

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

1) Polymer Cement

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

Table 3-13-1 Specifications of Polymer Cement

Property	Test Method	Unit	Specification
Thermal Expansion	ASTM C531	mm/mm℃	2.0×10^{-5}
Slant Shear Bond to Concrete	ASTM C882	N/mm^2	1.5 /above
Compressive Strength (7days x 20℃)	ASTM C579	N/mm^2	20 /above

2) Corrosion Protective Coating

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

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

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

3) Zinc Rich Primer

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

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

Property	Test Method	Unit	Specifications
Gloss @ 60° Angle	ASTM D 523	-	Flat
Adhesion	ASTM D 3359	-	Minimum 3A
Salt Spray Resistance	ASTM D3-37	-	Excellent
%Zinc by Weight in Dried Film Test	-	%	87.5±2

MAJOR REPAIR METHODS		
Defect/Deficiency	**Spalling/Exposed Rebar of Bored Pile**	**PLATE 3 - 13**
Remedial Measure	**Filling pile mortar/concrete**	

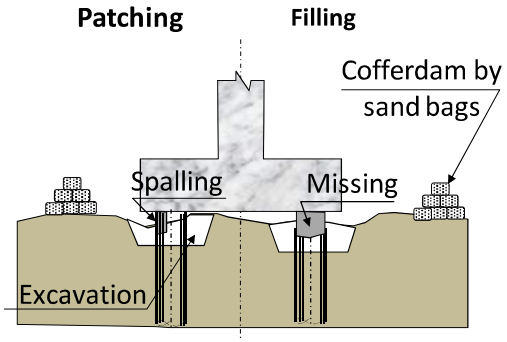
5-2 Work requirement

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

1) Excavation

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

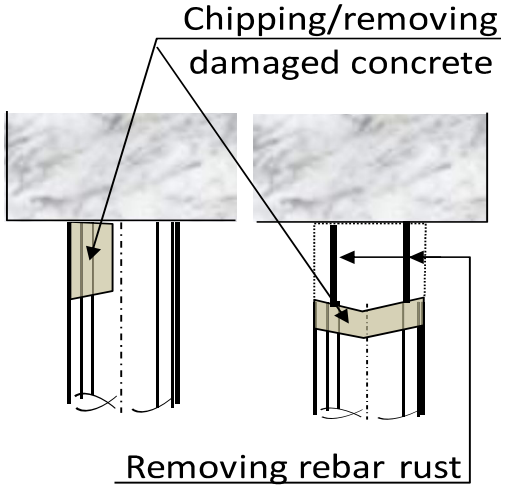
Temporary cofferdam by such as sand bags and a submersible pump shall be considered, if necessary. With consideration of safety, in case, excavation depth is required deeper than 1.0m, a new pile shall be constructed just nearby the damage pile.



2) Chipping/removing damaged concrete

Damaged concrete shall be removed by chipping works using an electrical jackhammer, chisel. Surface of the concrete shall be clean and dry.

Brushing or high-pressured air blowing will be applicable to this work.



3) Removing rust from rebar

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

4) Applying Epoxy primer

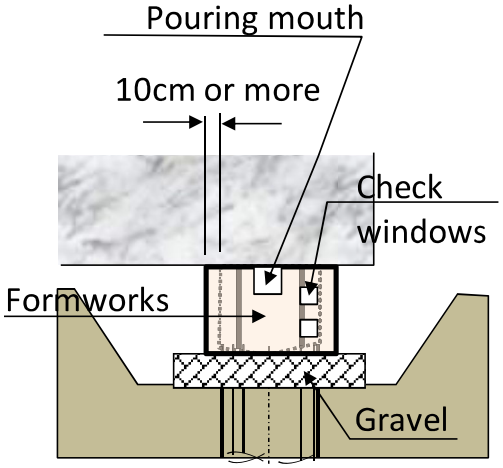
After curing zinc rich primer on rebar, Epoxy primer shall be applied on the concrete and rebar surface under dust and water free condition.

5) Installation of formworks

Patching of pile concrete will not require formworks.

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

Formworks shall be considered concrete pouring



mouth and concrete flow checking windows.

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

6) Applying polymer mortar/Pouring concrete

i) Applying polymer mortar

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

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

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

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

ii) Pouring concrete

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

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

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

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.

1) Curing

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

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

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

2) Remedial work

It is anticipated that remaining of some space between top of the pile concrete and the bottom of the pile cap due to sink of concrete. The Contractor shall check exist of space and carries out necessary remedial works such as injection of mortar grout or patching mortar, if space exist. The remedial work methodology shall be included into the Methodology Statement.

6. Measurement and Payment

6-1 Method of measurement

i) Patching of pile concrete

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

ii) Filling pile concrete

The Engineer will measure the length prepared for Filling pile concrete by the liner meter after the identified length of the pile top has been removed. The measured pay quantity will be those length verified by the Engineer and marked as unsound or delaminated concrete.

6-2 Basis of Payment

The price and payment per square meter of Patching pile concrete and payment per meter of Filling pile concrete shall include full compensation for removal of deteriorated concrete, surface cleaning and preparation, furnishing and placing all materials, labor,

equipment, tools. It shall also include construction and removal of formworks and other temporary works necessary to complete the Patching pile concrete/Filling pile concrete works.

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Scouring, Abnormal spacing**	**PLATE 3 - 14**
Remedial Measure	**Footing consolidation**	

1. Work description

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

Photo 3-14-1 typical Bridge scour

Photo 3-14-1 heavy Bridge scour

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

Photo 3-14-3 Placing Rip Rap

Placing Special Heavy Loose Rip Rap

Photo 3-14-4 Placing Sand Bags

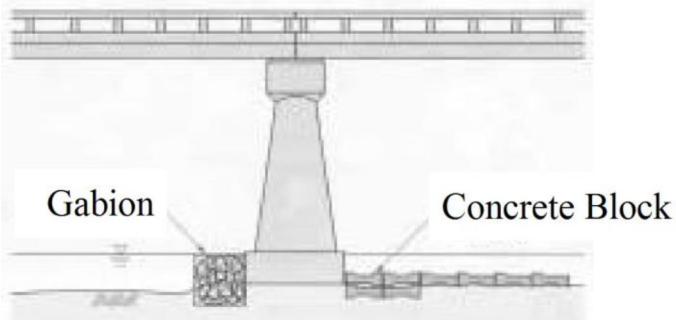
MAJOR REPAIR METHODS		
Defect/Deficiency	**Scouring, Abnormal spacing**	**PLATE 3 - 14**
Remedial Measure	**Footing consolidation**	

2. Application criteria

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

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

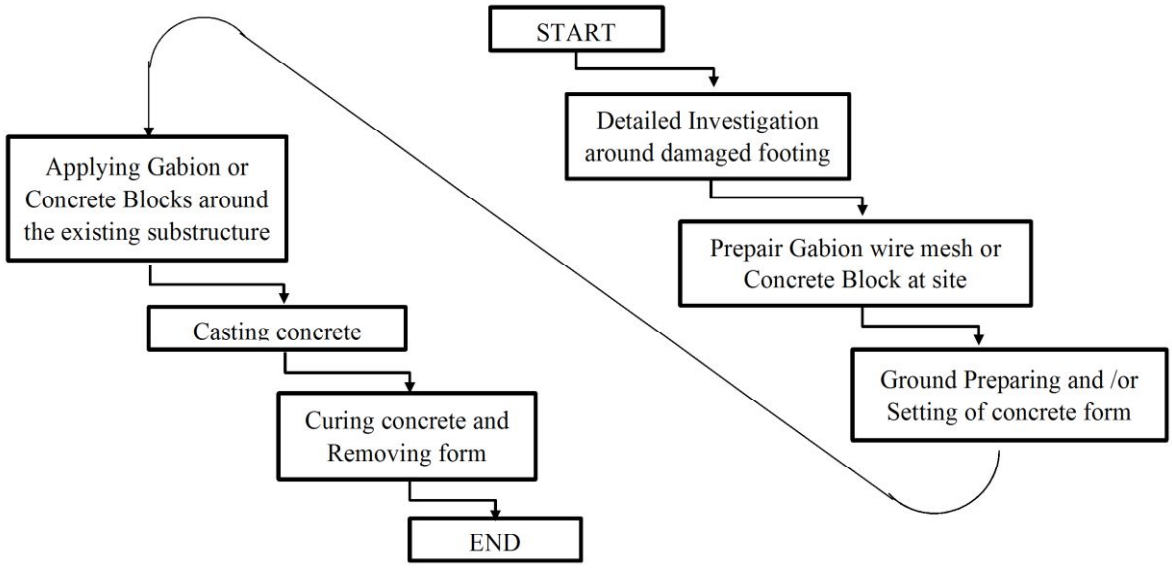
Figure 3-14-1 Examples of Footing Consolidation



3. Work sequence

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

Figure 3-14-2 Work sequence



MAJOR REPAIR METHODS		
Defect/Deficiency	**Scouring, Abnormal spacing**	**PLATE 3 - 14**
Remedial Measure	**Footing consolidation**	

4. Required Equipment/Tool and Material

4-1 Equipment/Tools

Following Equipment is necessary for consolidation of footing;

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

4.2 Material

Following Materials are necessary for consolidation of footing;

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

5. Requirement, Specification

5.1 Work requirement

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

1) Inspection

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

2) Preparation of work

Proper access arrangement for the work shall be ensured.

Removing damaged gabion or/and concrete blocks.

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Scouring, Abnormal spacing**	**PLATE 3 - 14**
Remedial Measure	**Footing consolidation**	

While removing the damaged wires, care shall be exercised not to disturb the existing portion of the gabion work which is in intact condition.

3) Filling missing material

Any missing infill material (stones/bricks/concrete blocks) shall be replaced by the approved infill material by the Engineer as per the specification. The new infill material shall be properly inserted and made to level with the existing surface so that the new work does not unduly protrude beyond the existing surface.

4) Casting new concrete

If casting of new concrete is approved, form work is done before the casting.

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

5) Curing concrete

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

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Scouring, Abnormal spacing**	**PLATE 3 - 14**
Remedial Measure	**Footing consolidation**	

6. Measurement and Payment

6-1 Method of Measurement

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

6.2 Basis of payment

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

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

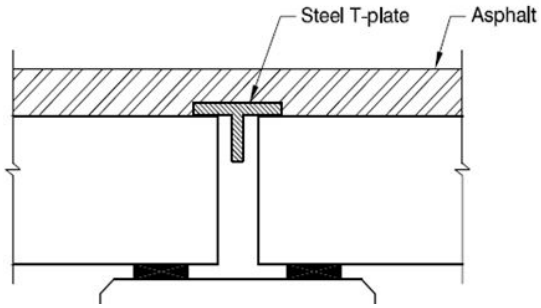
MAJOR REPAIR METHODS		
Defect/Deficiency	**Water Leakage/Puddle at Expansion Joint**	**PLATE 3 - 15**
Remedial Measure	**Replacement of small joint**	

1. Work description

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

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

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



Damaged Asphaltic plug joint

After removing Sealant of Asphaltic plug joint

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

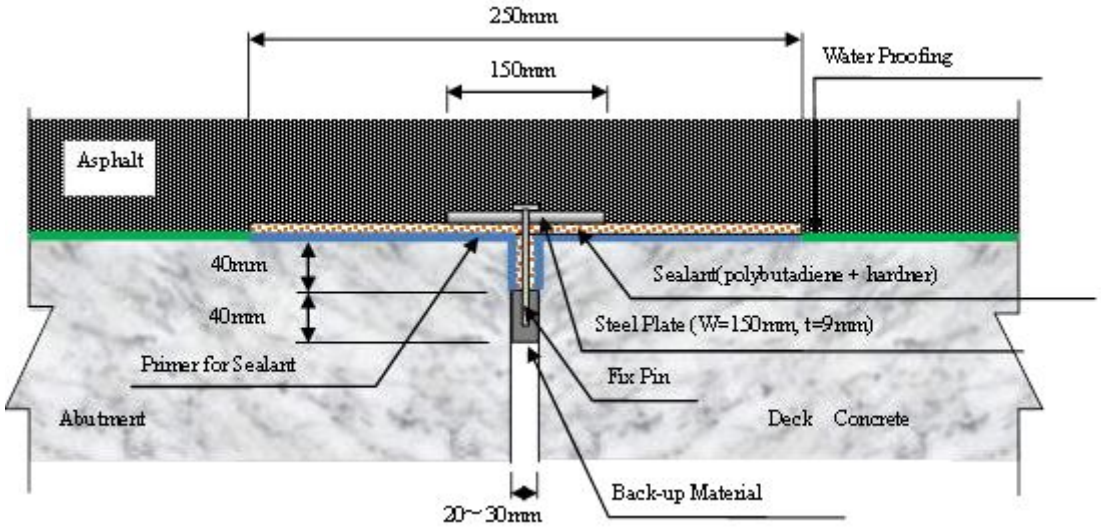
2. Application criteria

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

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

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

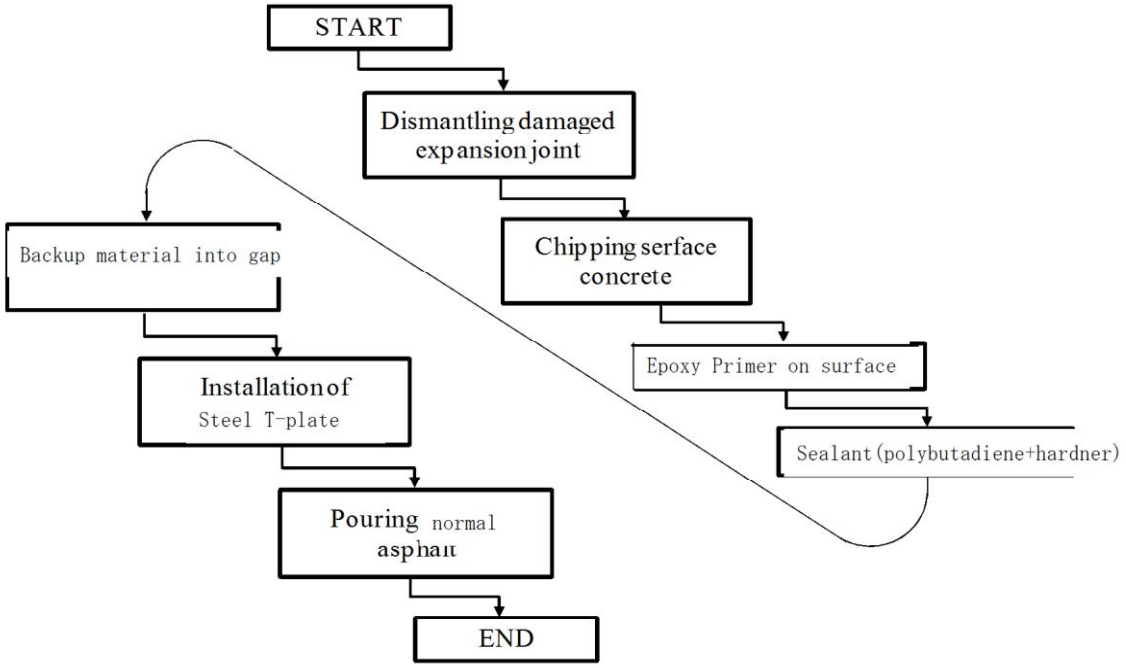
Figure 3-15-2 modified Buried joint with steel T-plate



3. Work sequence

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

Figure 3-15-3 Work sequence



4. Required Equipment/Tool and Material

4-1 Equipment/Tools

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

-Concrete Cutter

-Electric impact hammer/small jackhammer

-Gas burner

-Asphalt mini cooker

-Surface finisher

4.2 Material

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

-Steel Plate (w=150 mm, t=9 mm) with Fix pin

-Epoxy primer

-Sealant (polybutadiene + Hardener)

-Backup material for gap

-Normal Asphalt

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

5. Requirement, Specification

5.1 Material

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

1) Steel plate
   Pre-fabricated steel plate shall conform to ASTM A36 or equivalent.

2) Normal asphalt

   Asphalt compound shall conform to the requirements of the Table 2-5-1 of Plate 2-5 or equivalent.

3) Epoxy primer
4) Sealant
   Polybutadiene Sealant + Hardener
5) Backup material
   A compressive material used to fill the joint gap.

5.2 Works requirement

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

1) Dismantle Existing Damaged Asphalt Joint Sealant

   The damaged sealant due to heavy traffic, aging, etc. shall be dismantled.

2) Chipping surface concrete

   The surface of concrete at the location of the existing damaged joint shall be chipped off for purposes of installing new steel plate with fix pin.

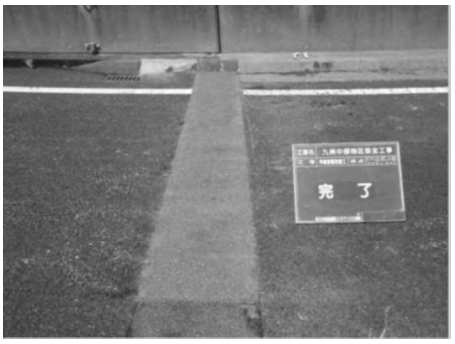
MAJOR REPAIR METHODS		
Defect/Deficiency	**Water Leakage/Puddle at Expansion Joint**	**PLATE 3 - 15**
Remedial Measure	**Replacement of small joint**	

3) Applying of Epoxy Primer and Sealant
The contractor shall submit shop drawing to be approved by the Engineer, prior to the installation of the steel plate.

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

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

6) Pouring normal asphalt
The normal asphalt shall be subjected to strict quality control especially for the temperature control requirements. Using mini asphalt cooker, normal asphalt shall be cooked until it reaches 180℃.
Traffic operations can resume after the Asphalt temperature is cooled down to 40℃.



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

6. Measurement and Payment

6-1 Method of Measurement

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

6.2 Basis of payment

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

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

MAJOR REPAIR METHODS		
Defect/Deficiency	**Abnormal Spacing at Expansion Joint**	**PLATE 3 - 16**
Remedial Measure	**Replacement of Steel joint**	

1. Work description

The quality and maintenance of the expansion joints are vital to the behavior of the bridges and their durability. Accordingly, it should be ensured that expansion joints are waterproofed as well as resistant to leakage.

When water leakage occurs at expansion joints, dirt, soil, gravel and water are collected on the bearing seat locations. This condition will initiate corrosion of steel members including the steel bearings, bottom flanges at ends of steel girder and steel connection accessories.

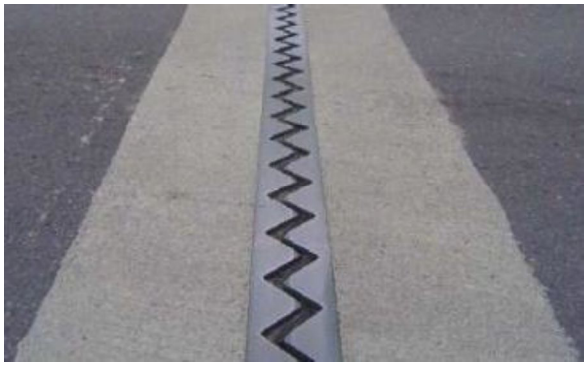
This repair method is intended for damaged steel type and rubber type expansion joints, which would be replaced with suitable water-proof type expansion joints.

Concrete cutter shall be used to cut both joint edges of the concrete surface to form a straight cutting line pattern. The defective expansion joint shall then be dismantled after chipping off the concrete with an electric jack hammer. The new expansion joint shall be installed with its top level matching the required finish surface. Concrete/grout shall be finally poured, leveled, and then cured.

Photo 3-16-1 and 3-16-2 shows example of water proof type steel expansion joint

Photo 3-16-1 Structure of the Steel Expansion Joint

Photo 3-16-2 After installation



2. Application criteria

Replacement of the steel expansion joint shall be implemented depending on condition of the expansion joint obtained through Bridge Condition Survey and daily maintenance activities or information from road users.

Following conditions can be referred as one of the Standards for decision of replacement of the steel expansion joint.

MAJOR REPAIR METHODS		
Defect/Deficiency	**Abnormal Spacing at Expansion Joint**	**PLATE 3 - 16**
Remedial Measure	**Replacement of Steel joint**	

-Water leakage: detected area >50%

-Abnormal Space/ serious Noise: Detected

-Difference in Elevation: >30mm at expansion gap

Meanwhile, followings can be referred as Standards for decision of replacement of the rubber expansion joint:

-Water leakage: detected area >50%

-Abnormal Space/ Noise: Detected

-Difference in Elevation: >30mm at expansion gap

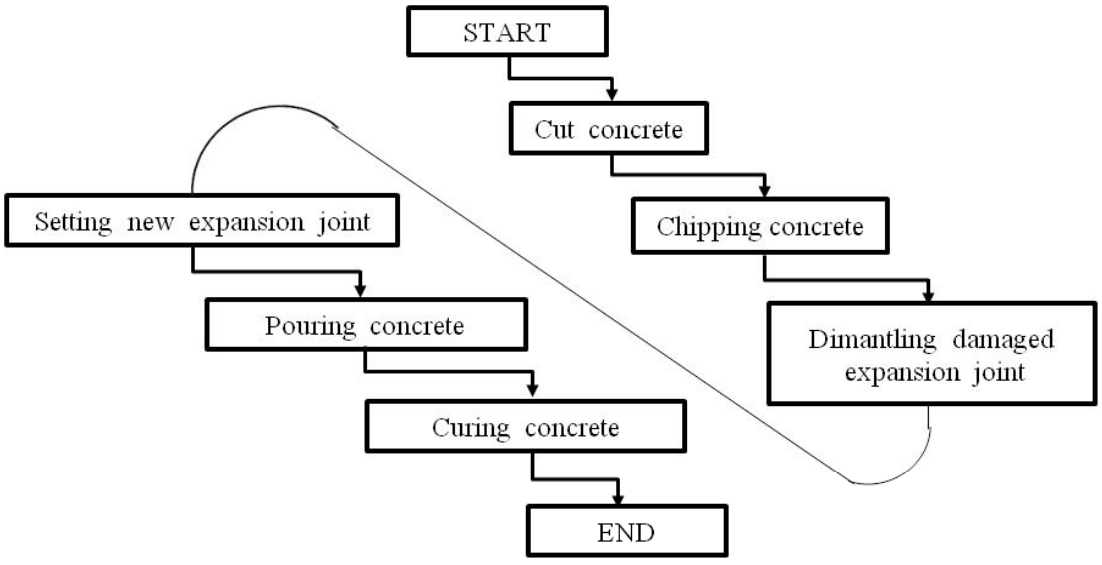
- Rubber seal dislodge or rupture: detected area >50%

-Deteriorated Sealant: Pourable joint sealant maybe almost lost off from location

3. Work sequence

Work sequence of replacement method of the Steel/Rubber expansion joint is as shown in Figure 3-16-1.

Figure 3-16-1 Work sequence



4. Required Equipment/Tool and Material

4-1 Equipment/Tool

MAJOR REPAIR METHODS		
Defect/Deficiency	**Abnormal Spacing at Expansion Joint**	**PLATE 3 - 16**
Remedial Measure	**Replacement of Steel joint**	

Following equipment/tool will be required for replacement works of the expansion joint.

- Concrete Cutter
- Electric impact hammer/small jackhammer
- Electric concrete vibrator
- Trowel

4-2 Material

- New Expansion Joint with water proof rubber
- Rebar (16 mm dia.)
- Concrete/grout

5. Requirement, Specification

5-1 Material

For new expansion joint

- Steel plates, anchor bars: ASTM A36 or equivalent
- Mortar/concrete: refer to Plate 3-3 Polymer cement mortar

The expansion joint rubber seal shall comply with the following specifications:

Table 3-16-1 Specification of Expansion Joint Rubber Seal

Property	Test Method	Unit	Specification
Tensile Strength	ASTM D 412	MPa	0.98(Min)
Elongation at break	ASTM D 412	%	100(Min)

The type and size of rubber seal for expansion joint should be determined based on manufacturer's instructions. The material test shall be applied for Tensile strength and Elongation to be approved by the Engineer.

5-2 Work requirement

(1) Cut concrete surface

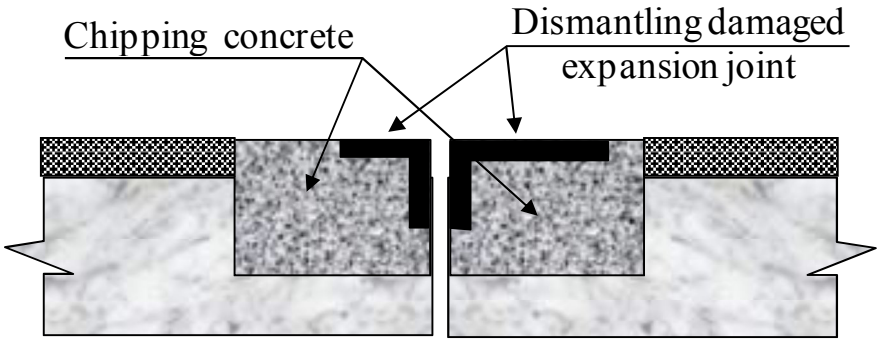
The Contractor shall submit for Engineer's approval, shop drawings for the new water-proofing type expansion joint and the construction plan for the dismantling and installation.

With a concrete cutter device, limits of concrete to be demolished near the existing expansion joints shall be defined in the transverse direction of the bridge deck (300 mm at each edge of the expansion gap).

(2) Chip off concrete and Dismantle Expansion Joint

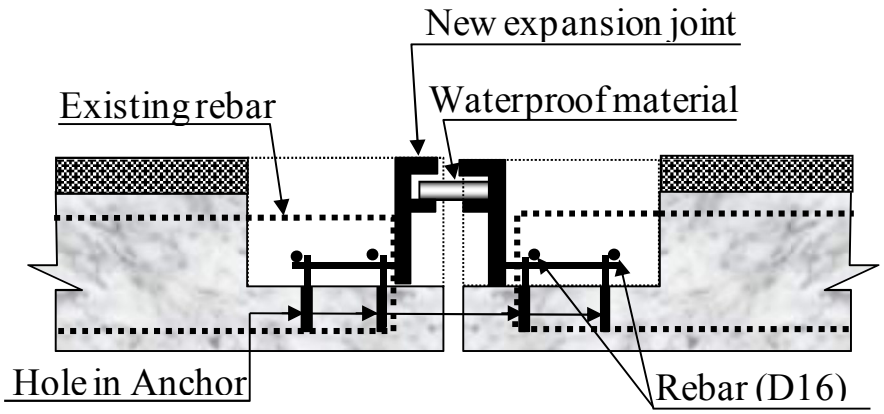
Based on the defined limits, the Contractor shall chip-off further the concrete with a jack hammer to expose the defective joint and portions of the existing reinforcement. After chipping off is accomplished, existing expansion joint material shall be removed

from its location.



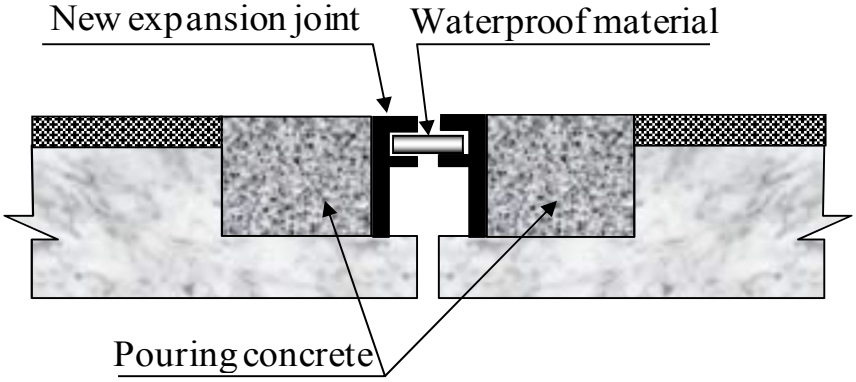
(3) Set up new expansion joint

The new expansion joint shall be installed to proper position considering the required finish level of the deck. The contractor shall submit for Engineers approval, result of measurement verifications for the proposed installation.



(4) Pouring concrete

The contractor shall submit for Engineer's approval, material test results of concrete. After approval, the contractor shall commence pouring of the concrete at identified locations near the new expansion joint. Final concrete shall be finished using trowel and shall be subjected to curing process.



MAJOR REPAIR METHODS		
Defect/Deficiency	**Abnormal Spacing at Expansion Joint**	**PLATE 3 - 16**
Remedial Measure	**Replacement of Steel joint**	

6. Measurement and Payment

6-1 Method of Measurement

The method of measurement for this method shall be by linear meter of joint length which will be defined by the Engineer.

6-2 Basis of Payment

The contract price paid per liner meter of seamless joint shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for executing all related works.

Pay Item No.	Name	Unit of Measurement
3-16-(1)	Replacement of Steel Expansion Joint	Linear Meter (m)
3-16-(2)	Replacement of Rubber Expansion Joint	Linear Meter (m)

MAJOR REPAIR METHODS		
Defect/Deficiency	**Water Leakage/Efflorescence on Deck Slab**	**PLATE 3 - 17**
Remedial Measure	**Waterproofing – Liquid Type**	

1. Work description

Concrete is naturally alkaline and therefore protects the steel. However, the effect of its contact with water and corrosive materials reduces the alkaline environment and allows an electrolytic process to start, thus corroding the rebar. The result of the corrosion and rusting is to expand the rebar which then damages and eventually destroys the surrounding concrete of the deck. The primary protection against this destructive damage is through installation of waterproofing membrane on the deck slab.

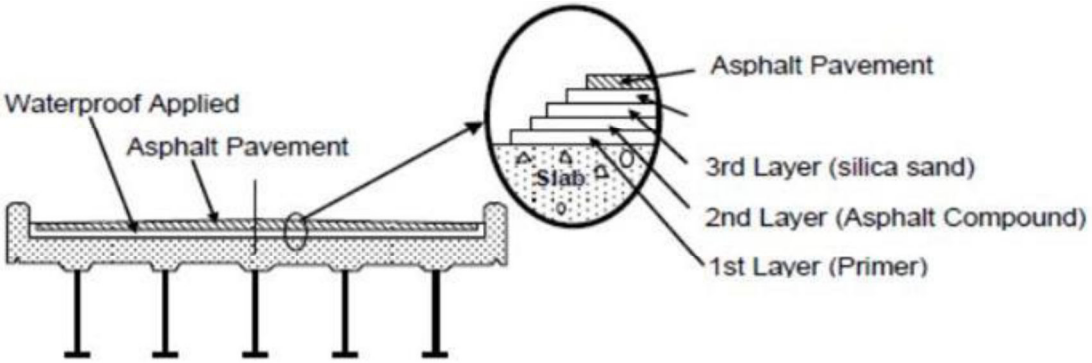
There are two bridge deck waterproofing methods i.e. **Sheet method** and **Liquid method**. The Sheet method is the recommendable method from the perspective of durability under traffic load, however need well trained technician and higher costs.

The Liquid Method consists of two types, namely: Rubberized Membrane Method (Photo 17-1) and **Asphalt Compound Method** (Photo 17-2).

Photo 17-1 Rubberized Membrane Method

Photo 17-2 Asphalt Compound Method

Figure 3-17-1 Sectional Component of Asphalt Compound Method



MAJOR REPAIR METHODS		
Defect/Deficiency	**Water Leakage/Efflorescence on Deck Slab**	**PLATE 3 - 17**
Remedial Measure	**Waterproofing – Liquid Type**	

2. Application criteria

The Rubberized Membrane Method mainly involves use of chloroprene rubber. The **Asphalt Compound Method** meanwhile involves use of asphalt mixed with special rubber, which is melted in a mechanically agitated heating process.

Features of both methods are summarized below:

(1) Rubberized membrane Method

- ✓ Application procedure is very simple and final product is proven to have good performance.
- ✓ Cost is higher than Asphalt Compound Method.
- ✓ In cases where removal of asphalt from deck is required (difficult to remove completely), this method would not be ideal since the roughness of the deck surface, reduces its waterproofing efficiency.

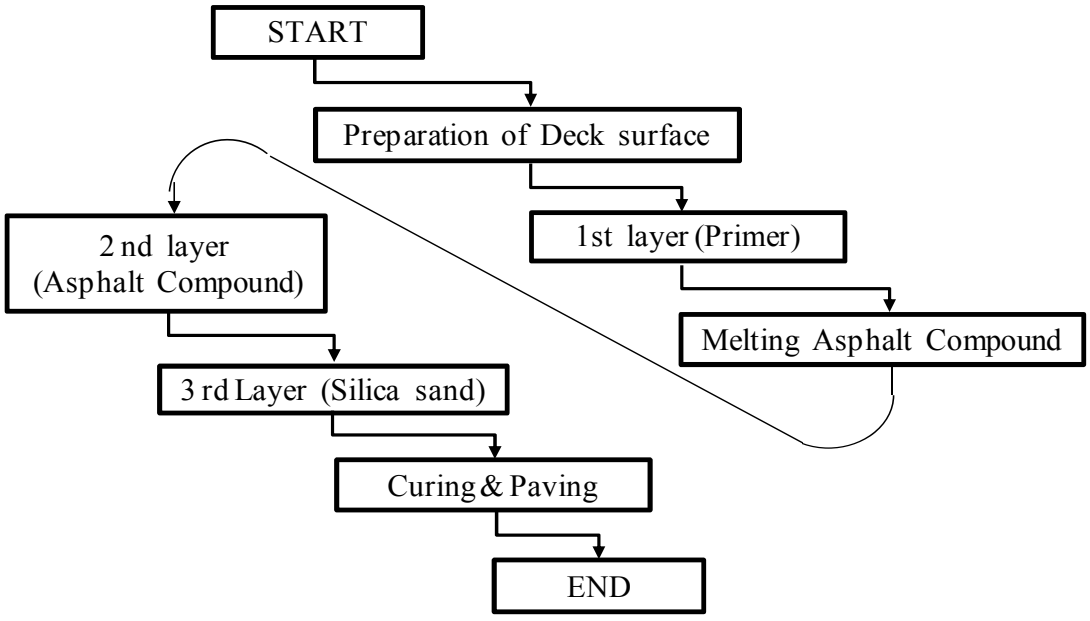
(2) Asphalt Compound Method

- ✓ Less costly materials.
- ✓ Equipment costs such as kettle and heating tool, including its inland transport cost tend to increase construction cost.

3. Work sequence

Work sequence of Asphalt Compound Method is as shown in Figure 3-17-2.

Figure 3-17-2 Work sequence



MAJOR REPAIR METHODS		
Defect/Deficiency	**Water Leakage/Efflorescence on Deck Slab**	**PLATE 3 - 17**
Remedial Measure	**Waterproofing – Liquid Type**	

4. Required Equipment/Tool and Material

4-1 Equipment/Tools

The following Equipment is necessary for Asphalt Compound Waterproofing Method:

-Kettle with Heater

-Roller Brush or Hair brush

-Rubber Brush

4-2 Material

-Primer

-Asphalt Compound Membrane

-Silica sand

5. Requirement, Specifications

5-1 Material

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

1) Primer

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

2) Asphalt Compound

Waterproofing by asphalt compound membrane shall conform to the requirements of the specifications shown in Table 3-17-1, or equivalent ASTM Specifications.

Table 3-17-1 Specification of Asphalt Compound

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

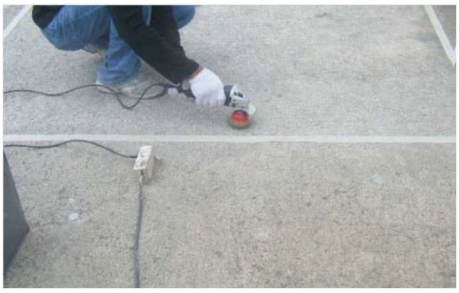
5-2 Work Requirement

The Contractor shall submit shop drawings for the waterproofing application, slab drain and spray mesh and the Methodology Statement of the Work to the Engineer for his review and approval. The performance test for waterproofing shall be applied by contractor to be approved by the Engineer.

1) Surface preparation

The deck concrete, including curbs, and sidewalks

must be completely dry and cured at least 14 days before application of primer or membrane. The existing surface of the concrete shall be completely sandblasted or shot-wire brushed to expose sound, laitance-free concrete. All dirt and debris shall be removed and disposed of, leaving a prepared surface satisfactory for primer coating. Primer coating and waterproofing shall not commence until the Engineer has accepted all preparation works.



If the existing asphalt pavement is covered on the deck slab, the pavement shall be stripped-off totally using pavement scraper.

2) Primer coat

Prior to the application of the primer coat, the concrete surface shall be air blasted to remove all dust and any other foreign materials. Primer coat material shall be applied with approved equipment which will provide uniform application at the required rate.

The primer coat shall be applied only when the concrete is dry and clean, and when the air and concrete surface temperatures are above 10^{o}C. Waterproofing equipment or material shall not be permitted on the primer coat until it has fully cured and is completely tack-free.

3) Melting Asphalt Compound

Asphalt compound shall be melted in the mechanically agitated heating tool and mixed in a kettle. This unit shall keep the contents continuously agitated until the material can be drawn free flowing and lump-free from the mixing unit at a temperature recommended by the manufacturer.

An approved heating and mixing kettle shall be used to heat the hot-applied rubberized asphalt membrane. The kettle shall be of a double boiler oil transfer type with a built-in agitator. It shall be equipped with permanently installed dial type thermometers to measure the temperature of the melted compound and the oil.

4) Application of Asphalt Compound

Asphalt Compound shall not be applied until the primer has cured completely. The

asphalt membrane shall be applied within the temperature range recommended by the manufacturer, to the clean, primer-coated concrete deck, to form a uniform film having a minimum thickness of 4 mm ~ 6 mm (Approximately 3-2kg/m^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.

5) Spreading Silica Sand for protection

Silica sand shall be spread as protection to the waterproofing layer, while the membrane on the deck is still hot. Excess silica sand shall be removed by broom. The silica sand to be used shall be approximately 0.7 kg/m^2. (Refer to the Manufacturer's instructions)

6. Measurement and Payment

6-1 Method of Measurement

Deck slab waterproofing membrane by Asphalt Compound Method, complete in place and accepted, will be measured by square meters of bridge deck. Material placed on curb faces and overlaps will not be measured. Tack coat and asphalt overlay will be measured and paid for as provided under the respective items specified in the RHD Standard Specification.

6-2 Basis of payment

Payment for deck waterproofing by Asphalt Compound Method will be made at a unit price bid per square meter of deck waterproofed, which shall cover full compensation for the cost of all labor, equipment and materials required for the preparation of the concrete deck surface including sandblasting, supply and application of the tack coat, asphalt membrane, rubber membrane and protection board, handling and controlling of traffic, and for all other work items necessary for the satisfactory completion of the work.

MAJOR REPAIR METHODS

Defect/Deficiency	Water Leakage/Efflorescence on Deck Slab	PLATE 3 - 17
Remedial Measure	Waterproofing – Liquid Type	

Pay Item No.	Name	Unit of Measurement
3-17	Waterproofing Asphalt Compound Method	Square Meter (m^2)

MINOR REPAIR METHODS		
Defect/Deficiency	**Functional disorder bearing**	**PLATE 3-18**
Remedial Measure	**Repainting of steel bearing**	

1. Work description

Due to thin paint coverage on steel surfaces or formation of pin-holes in paint, the steel surface may get exposed to atmosphere resulting in initiation of corrosion. Due to corrosion, the sliding function of steel bearing is inhibited. Therefore, cleaning of corrosive surface and repainting is important to improve the sliding function of bearing.

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

2. Application criteria

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

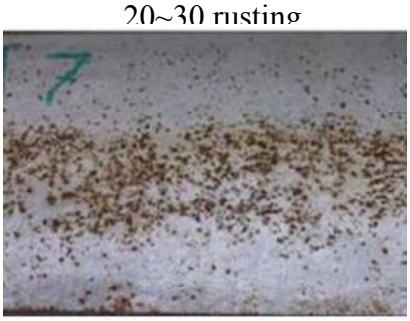
Table 3-18-1 Degree of rusting and surface preparation

Affected area	Description of degree of rusting	Surface preparation	Reference Photos of surface preparation	
			Before	After
10-20 %	Grade-1: Corrosion is partially visible but not severe. Peeled-off coating film is partially visible	Remove old coating film, rust with disk grinder, scraper and wire brush	Photo4-1	Photo4-3
20-30%	Grade-2: Corrosion is partially severe on steel surface and coating film is almost visible but partially deteriorated due to corrosion	Remove old coating film, rust with scraper and wire brush partially revealing the steel texture	Photo4-2	Photo4-4

Steel surfaces affected by corrosion

Photo18-1 Surface area of 10~20% rusting

Photo18-2 Surface area of 20~30 rusting



MINOR REPAIR METHODS		
Defect/Deficiency	**Functional disorder bearing**	**PLATE 3-18**
Remedial Measure	**Repainting of steel bearing**	

Corrosion affected steel surfaces after surface preparation

Photo18-3 Less severe corrosion

Photo18-4 More severe corrosion

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

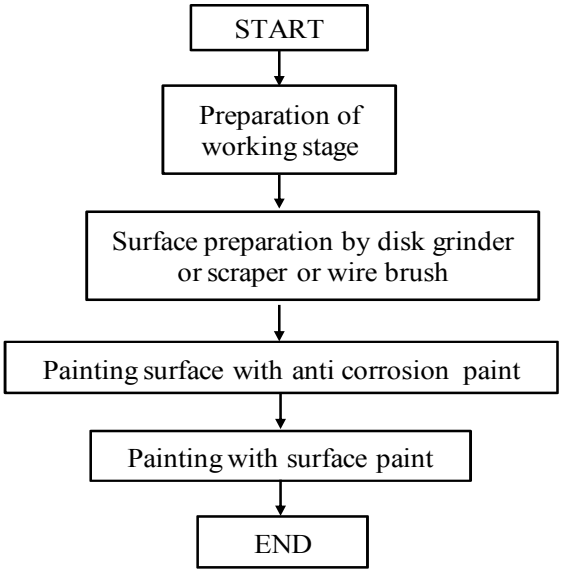
Where condition of paint is evaluated as Grade-2 (affected surface 20-30%) with loss of section within 20%, special anticorrosion paint shall be applied to restrict corrosion from progressing further.

Galvanized and heavily corroded steel surfaces shall also be treated with special anticorrosion paint systems. Patch repair with ordinary aluminum paint is not suitable for repair of corrosion affected galvanized steel surfaces. As shown in the photos, special anticorrosion paint shall be applied to heavily corroded steel portions.

3. Work sequence

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

Figure 2-4-1 Work sequence



MINOR REPAIR METHODS		
Defect/Deficiency	**Functional disorder bearing**	**PLATE 3-18**
Remedial Measure	**Repainting of steel bearing**	

4. Required Equipment/Tool and Material

4.1 Materials

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

4.2 Tools/Equipment/

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

5. Requirement, Specification

5-1 Material

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

For special anticorrosion paint, the materials shall satisfy the test requirements indicated in the relevant ASTM specifications as follows:

Table 2-4-2 Specification of Aluminum paint

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

5-2 Work requirement

1) Scaffolding

Scaffolding shall be installed for close access to the corrosion affected surfaces of the steel bearings to be repaired. Standard scaffoldings may be used, however mobile scaffolding/inspection vehicle may be found suitable as it allows for free movement in most cases and provides access with convenience to various parts of a bridge, particularly for bridges with high elevation or deep river crossings.

MINOR REPAIR METHODS		
Defect/Deficiency	**Functional disorder bearing**	**PLATE 3-18**
Remedial Measure	**Repainting of steel bearing**	

2) Preparation of Steel Surface:

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

Groves and ridges formed on the affected surface shall be removed with power grinder. Where appropriate, as an alternative, epoxy resin filler may be used to fill the surface to a smooth and even finish. Where depth of roughness is within 0.5 mm, paint adequacy and durability can be achieved without application of multiple coats of surface leveling paints. Thickness of each coat shall not exceed the limiting value recommended in the paint manufacturer's specifications.

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

3) Application of Paint

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

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

- Layer-1: 250μm
- Layer-2: 250μm

Anticorrosion paint shall be applied in accordance with the stipulations of paint manufacturer's specifications. Minimum total film thickness for aluminum paint shall be not less than 125 μm.

Roval paint is recommended for galvanized member touchup painting.

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

- Layer-1: 40μm
- Layer-2: 40μm

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

6. Measurement and Payment

6.1 Method of Measurement

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

6.2 Basis of Payment

Payment shall be made based on unit price per square meter area of field touchup painting complete in all respect and approved, including all labor, services of technical service advisor, equipment, tools, materials and work incidentals including all necessary storage and hauling to and from the bridges as repaired, and collection and storage of all materials within the work area.

Pay Item No.	Name	Unit of Measurement
2-4	Repainting of steel bearing	Square Meter (m^2)

MAJOR REPAIR METHODS		
Defect/Deficiency	**Difference in Level due to Defect of Bearing**	**PLATE 3 - 19**
Remedial Measure	**Replacement of Rubber Bearing**	

1. Work description

Function of a bearing shoe is transferring all load from a superstructure including own load of the superstructure to a substructure such as an abutment and a pier.

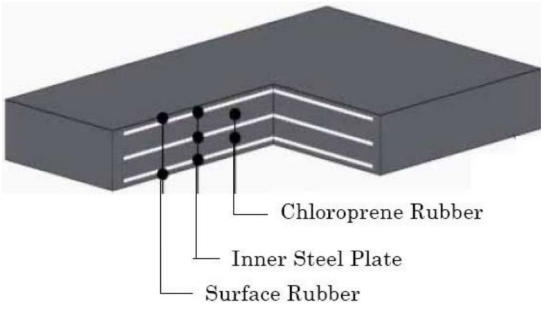
In case the bearing shoe has some defect, a road surface will lose its flatness and causes impact to both of the superstructure and substructures. This impact will to be a cause of damages to the superstructure and substructures.

Meanwhile, rusting condition of the bearing shoe area is one of the most serious areas due to narrow space and concentration of debris and water.

Effective service life of elastomeric bearings is estimated to be 15 – 25 years. As the material ages during its serviceability period, it exhibits severe bulging or cracking. These are signs that the elastomeric bearings need to be replaced.

Replacement with new bearing shoe should be performed strictly in accordance with the relevant technical requirements and recommendations provided by the bearing manufacturers. Installation should be performed by highly experienced staff subject to close supervision.

Usually, the jack-up girder technique is utilized to allow for replacement of bearings. During replacement of the bearings, traffic may remain opened but with imposed restriction on passing speed as safety precaution. The girder shall be jacked up to around 5 mm to 10 mm, with one jack stroke.



2. Application criteria

Replacement of bearing shall be implemented if existing rubber bearings already exhibited severe cracks and abnormal bulging. Old steel bearings need to be replaced especially if loose connections were found.

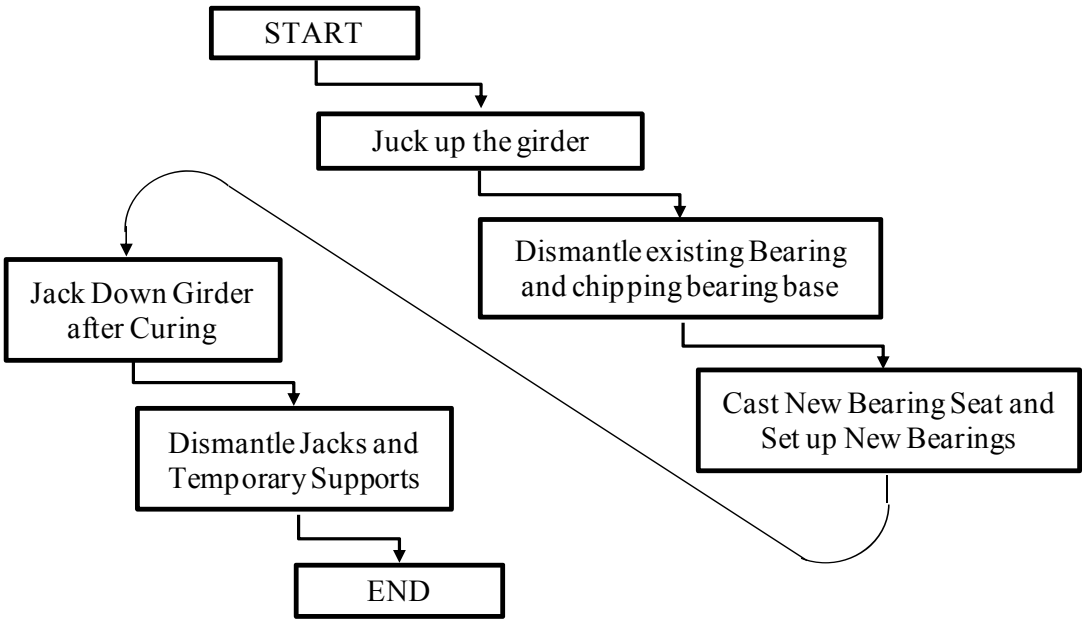
The capacity of the new bearing should be the same as the old bearing, subject to approval of the Engineer.

MAJOR REPAIR METHODS		
Defect/Deficiency	**Difference in Level due to Defect of Bearing**	**PLATE 3 - 19**
Remedial Measure	**Replacement of Rubber Bearing**	

3. Work sequence

Work sequence of replacement method of the Rubber bearing shoe is as shown in Figure 3-19-1.

Figure 3-19-1 Work sequence



4. Required Equipment/Tool and Material

4-1 Equipment/Tool

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

- Hydraulic Jack
- Electrical Jackhammer
- Portable generator
- Trowel

4-2 Material

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

- Elastomeric bearing pads.
- Rebar
- Mortal/concrete

MAJOR REPAIR METHODS		
Defect/Deficiency	**Difference in Level due to Defect of Bearing**	**PLATE 3 - 19**
Remedial Measure	**Replacement of Rubber Bearing**	

5. Requirement, Specification

5.1 Material

(1) Bearing Pads

Elastomeric bearing pads shall be confirmed to AASHTO M251.

Property	Test Method	Unit	Specification
Hardness, Durometer	ASTM D 2240	—	60±5

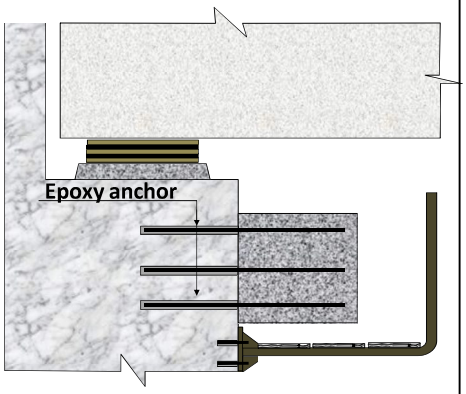
The material test shall be applied for Hardness test to be approved by the Engineer.

5.2 Work requirement

(1) Installation of jacking stages

The Contractor shall submit the shop drawings of jack up bracket staging and the working staging to be approved by the Engineer.

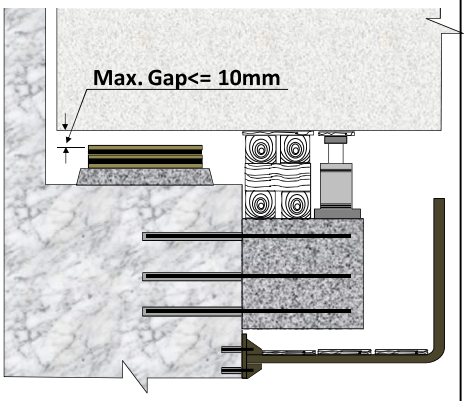
The jack up bracket shall strong enough against reaction from jacking load. Concrete of the bracket shall be cured until concrete strength developed required strength.



(2) Jack up girder

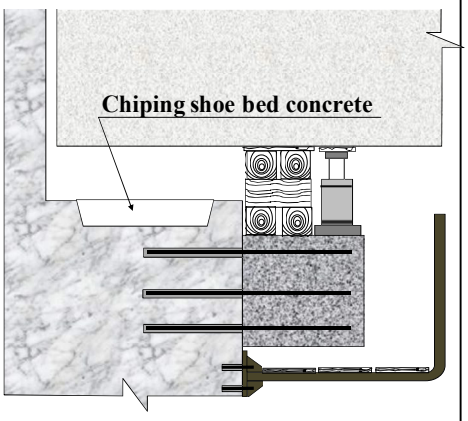
The jack capacity shall be agreed with the Engineer considering dead load and live load during the replacement work.

The surface of expansion joint shall be secured to provide safety for passing traffic during jacking up process. Moreover, the height difference between surface of abutment and girder shall be kept smaller than 10 mm.



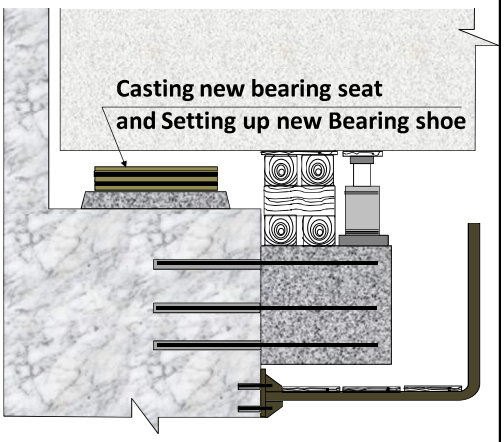
(3) Casting bearing seat and set up new bearings

The Contractor shall submit shop drawings for the new bearing seat to be approved by the Engineer, prior to execution of related works including concrete chip off. After providing temporary support for the girders near the bearing locations, old bearings shall be dismantled. Position and level for the new bearings shall be set-up accordingly.



(4) Jack down girder After Curing

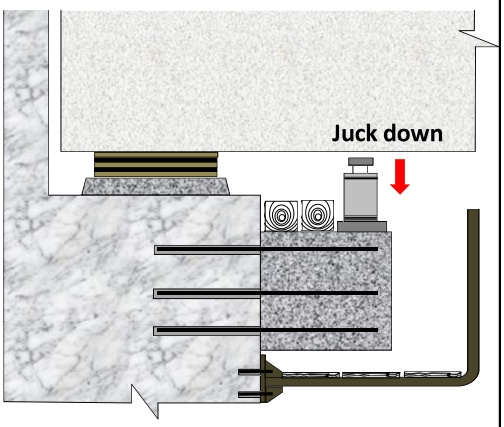
Mortar/concrete shall be cured to achieve sufficient strength for supporting the load reactions. The Contractor shall submit test results of specimen strength in accordance with the specifications, subject to approval of the Engineer. If the test results are acceptable, jack down the girder to consequently release load reactions from the jacking device.

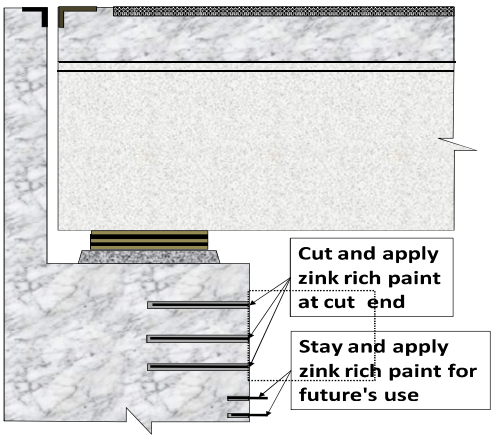


(5) Dismantle Jacks and Temporary Supports

When the reaction is safely transferred from the jack to the new bearing, jacking device shall be dismantled.

Temporary jacking bracket and staging shall be removed, epoxy anchors for bracket shall be cut at the surface of the concrete and cut end shall be applied zinc rich paint. Staging anchor bolts shall be remained with application of zinc rich paint for future's use.





6. Measurement and Payment

6.1 Method of Measurement

The method of measurement for replacement of bearings shall be by number (quantity) approved by the Engineer.

MAJOR REPAIR METHODS		
Defect/Deficiency	**Difference in Level due to Defect of Bearing**	**PLATE 3 - 19**
Remedial Measure	**Replacement of Rubber Bearing**	

6.2 Basis of Payment

The quantities, measured as prescribed above shall be paid for at the contract unit price which shall cover full compensation for furnishing, preparing, fabricating, transporting, placing and installation. The new rubber bearing, jack up work, chipping concrete, pouring concrete/grout, jack down work and other activities are deemed included in priced item.

Pay Item No.	Name	Unit of Measurement
3-19	Replacement of Rubber bearing shoe	Number

MAJOR REPAIR METHODS		
Defect/Deficiency	**Defect of reinforcing material**	**PLATE 3-20**
Remedial Measure	**Re-bonding of strengthening plate**	

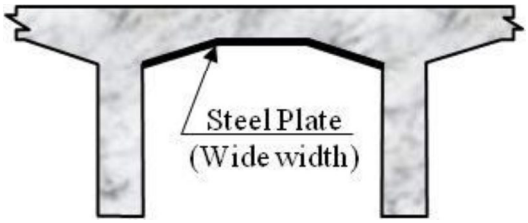
1. Work description

The technique of bonding steel plates to concrete deck slab using epoxy adhesives has been used on a number of bridges to enhance their load carrying capacity. The effect of bonding a plate to the tension side of a reinforced concrete section is to increase the depth from the compression side to the neutral axis and the area of effective reinforcement, thus, increasing the moment of resistance of the section.

The steel plate bonding with Wide plates are used often, however the durability of adhesives of plates is limited to 10 years or even shorter for former Injection method with former adhesives. If defect of strengthening steel plate is found widely, the Re-bonding of plates is required.

Figure 3-20-1 Steel Plate Bonding

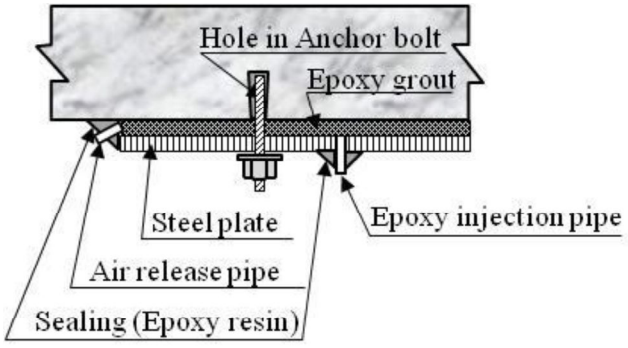
Wide Plate Type (Injection Method)



2. Application criteria

Wide Plate Type with Injection Method is usually applied for deck slabs in which rebars in both of directions are damaged. The bonding method of the steel plate is by Injection Method in which the steel plate is bonded to concrete deck slab by injection of Epoxy Resin into space between concrete deck slab and the steel plate set by anchor bolts as shown Figure 3-20-2.

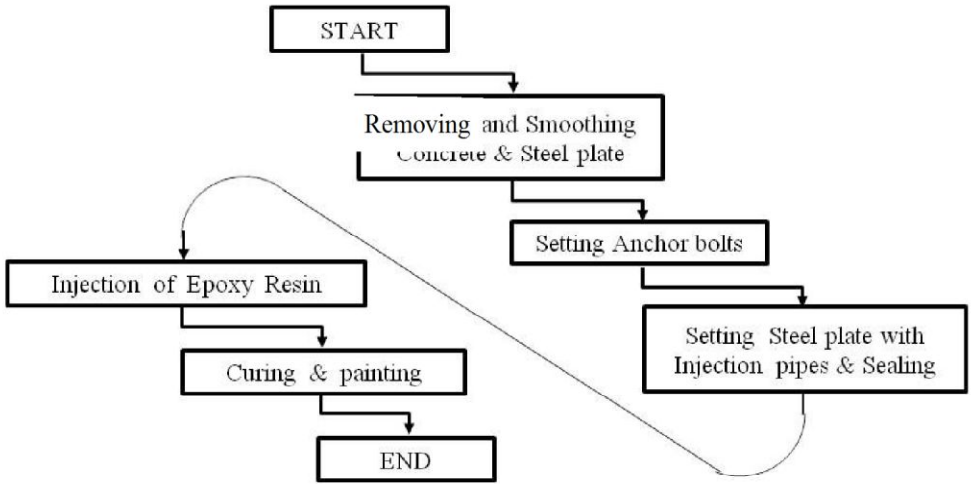
Figure 3-20-2 Steel Plate Bonding -Injection Method)



3. Work sequence

Defect of de-bonding is caused by bad former epoxy grout quality or insufficient injection work. Corrosion of steel plates is another damage type. If the de-bonding is found partly, partly Injection method is chosen. By large defect is chosen, totally removing plates, and then full re-bonding is recommended. Work sequence of Re-bonding of strengthening plate Method is as shown in Figure 3-20-3.

Figure 3-20-3 Work sequence of Re-Bonding-Injection Method



4. Required Equipment/Tools and Material

1) Equipment/Tools

The following Equipment/Tools will be necessary for Steel Plate Bonding-Injection Method works:

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

2) Materials

The following materials will be necessary for Steel Plate Bonding-Injection Method works:

MAJOR REPAIR METHODS		
Defect/Deficiency	**Defect of reinforcing material**	**PLATE 3-20**
Remedial Measure	**Re-bonding of strengthening plate**	

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

5. Requirement, Specifications

5-1 Material

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

1) Steel Plate
Steel Plate is in accordance with ASTM A36.

2) Epoxy Grout
Epoxy Grout (Epoxy Resin Adhesive) shall conform to the requirements of the specifications shown in Table 3-20-2, or equivalent ASTM Specifications.

Table 3-20-2 Specification of Epoxy Grout

Property	Test Method	Unit	Specification
Specific Gravity	ASTM D792M	-	3-2±0.2
Viscosity	ASTM D2393	mPa·s	5000 below
Flexural Strength	ASTM D790M	N/mm^2	40 /above
Compressive Strength	ASTM D695M	N/mm^2	50 /above
Compressive Young's Modulus	ASTM D695M	N/mm^2	1500 /above
Tensile Strength	ASTM D638M	N/mm^2	20 /above
Slant Bond Strength to Concrete	ASTM C882	N/mm^2	15 /above
Tensile Shear Bond to Steel	ASTM D1002	N/mm^2	15 /above

3) Epoxy Sealant

Epoxy Sealant shall conform to the requirements of the specifications shown in Table 3-20-3, or equivalent ASTM Specifications.

MAJOR REPAIR METHODS		
Defect/Deficiency	**Defect of reinforcing material**	**PLATE 3-20**
Remedial Measure	**Re-bonding of strengthening plate**	

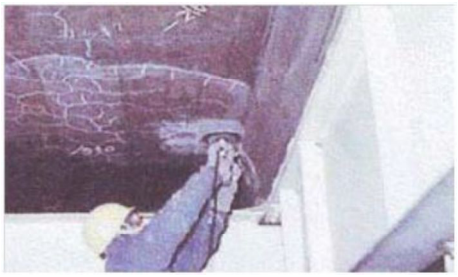
Table 3-20-3 Specification of Epoxy Sealant

Property	Test Method	Unit	Specification
Specific Gravity	ASTM D792	-	1.50±0.3
Flexural Strength	ASTM D790M	N/mm^2	40 above
Compressive Yield Strength	ASTM D695M	N/mm^2	50 above
Tensile Strength	ASTM D638M	N/mm^2	30 above
Tensile Shear Bond Strength	ASTM D1002	N/mm^2	10 above
Slant Shear Bond to Concrete	ASTM C882	N/mm^2	15/above

5-2 Work requirement

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

1) Surface preparation



The concrete surface of an existing member will usually be contaminated and have out-of-plane, imperfections and will therefore require preparation before plates are bonded to it. Cracks wider than 0.2 mm which could reduce adhesion and areas of concrete that appear porous should be sealed with a compatible resin.

The surface of the steel to be bonded must be completely free of any mill scale, rust, grease or other contaminants. For successful adhesion of the resin, the contact surfaces of the steel plates should be degreased and blast cleaned at the fabricator's premises. The primer, for the epoxy resin adhesive, should be an epoxy-based system compatible with the adhesive.

2) Setting Anchor bolts

Anchor bolts are required to temporarily support steel plates in the event of setting on the deck slab with an average gap of 5mm between the slab surface and steel plate. The bolt spacing should be sufficient to prevent deflection of the bonded plate

within the defined space.

3) Setting Steel Plate

Injection pipes are attached to the steel plate. Joints between steel plates are welded at site. Minimum plate thickness should not be less than 4 mm in order to avoid distortions during grit blasting and handling on site. Concrete structures to which plates are to be bonded shall be invariably smoothened and surface burnished using a disc grinder.

4) Sealing

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

5) Injection Epoxy Grout

Procedure trials should always be carried out to confirm the quality of the method of application and acquaint the applicators with the materials to be used. Where epoxy grout is to be injected, the mixing continuously takes place during injection. The epoxy grout shall be injected through injection pipes, gradually withdrawn as filling takes place.

The manufacturer's instructions on safe use of resins should be followed.

6) Curing and Painting

To protect the adhesive against moisture ingress, the edges of the plate should be sealed with resin putty or mortar after the adhesive has cured. A suitable chamfer/fillet

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

6. Measurement, Payment

6-1 Method of Measurement

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

6-2 Basis of Payment

The quantity measured as prescribed above, shall be paid for at the contract unit price. Epoxy injection of cracks will not be paid for directly and is considered subsidiary to the works.

This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related services necessary for reinforcing the deck slab by steel plate, as detailed in the plans and specifications.

Pay Item No.	Name	Unit of Measurement
3-20	Re-bonding of strengthening plate	Square Meter (m^2)

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