Bridge Repair Method

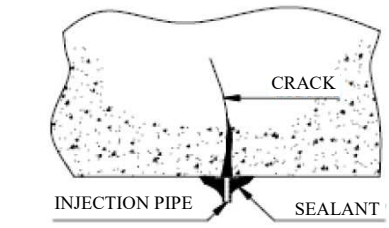
No.1-1 Crack Repair Method (Crack Injection)

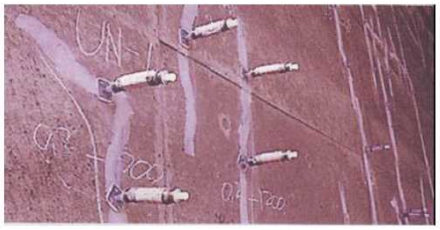
1. Description of Repair Method

This method involves crack repairs to concrete structures, particularly to deck slab as shown in Figure AP1.1.1. The works include preparation of concrete surface, insertion of pipe fitting 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. Said person should be qualified based on his previous experience, and approved by the Engineer.

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





(After Injection)

Figure AP1.1.1 Crack Injection Method

2. Application Criteria

This is used to restore structural soundness of structures exhibiting inactive cracks. Crack with more than 0.2mm up to 1.0mm widths can be bonded and sealed by injecting repair material.

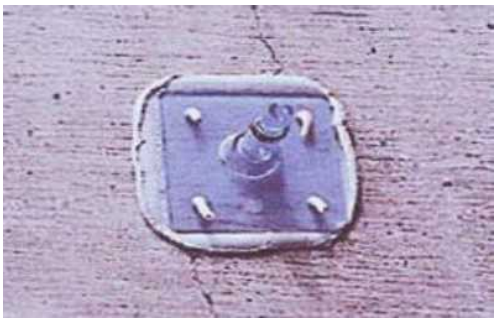
3. Work Sequence

3.1 Cleaning of Cracks

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

3.2 Bonding of Fitting Pipe

Pipe fitting are bonded with the adhesive to the crack center for injecting repair material. Spacing of the pipes varies between 150mm to 500mm, 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.

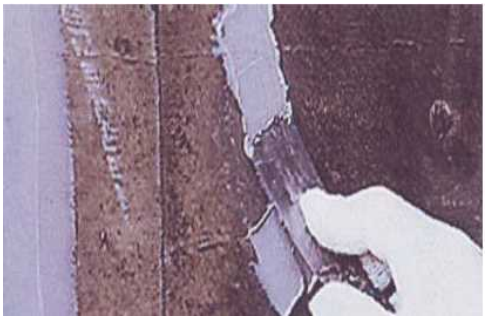


Bridge Repair Method

No.1-1 Crack Repair Method (Crack Injection)

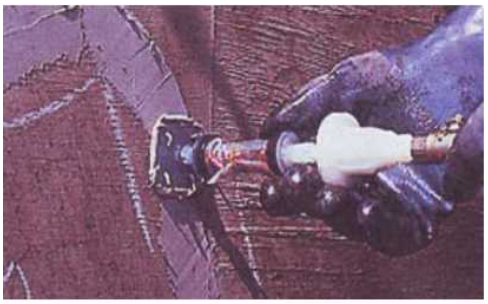
3.3 Sealing of Cracks at the Surface

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



3.4 Fitting of Injector

Connect the terminal of the injector to the pipe fittings.



3.5 Injection of repair material

Epoxy shall be injected using air-activated epoxy injection guns as shown in Figure AP1.1.2. Injection is performed on the pipe fitting. Duration of the injection operation shall be in accordance with the supplier's instruction.
If the crack is vertical, commence the injection of epoxy at the lowest pipe fitting, until the epoxy exudes from the pipe fitting above. For horizontal cracks, epoxy injection is carried out from one end of the crack to the other, in a similar manner.

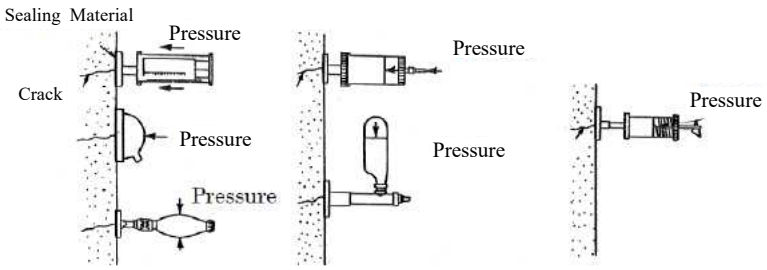


Figure AP1.1.2 Injection of repair material

3.6 Curing of Injected Material

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

Bridge Repair Method

No.1-1 Crack Repair Method (Crack Injection)

4. Required Materials and Tools/Equipment

4.1 Required Material

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

4.2 Required Tools/Equipment

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

5. Specification

5.1 Material Specifications

1) Epoxy Resin for Injection

Epoxy resin should be compatible with the host concrete and should have the properties listed in Table AP1.1.1. Testing of materials shall be in accordance with the relevant standards or equivalent ASTM specifications.

Table AP1.1.1 Specifications of Epoxy Resin for Injection to Superstructure

Property	Test Method	Unit	Specification
Viscosity	JIS K 6833/ASTM D2393	mPa-s*	≤ 1000
Pot life	-	Minute	60
Specific Gravity	JIS K 7112/ASTM D792	-	1.15± 0.1
Compressive Strength	JIS K 7208/ASTM D695	N/mm^2	≥50
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥40
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥10
Slant Shear Bond Strength to Concrete	JIS K6852/ASTM C882	N/mm^2	15/above
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM D7234	N/mm^2	≥1.5 CF

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

2) Sealant

The epoxy-based sealant material should be compatible with the injection material and should have the properties listed in Table AP1.1.2. The testing of materials shall be in accordance with the relevant standards below or equivalent ASTM specification.

Bridge Repair Method

No.1-1 Crack Repair Method (Crack Injection)

Table AP1.1.2 Specifications of Epoxy-based Sealant to Girder

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

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

5.2 Construction Requirement

(1) Preparation of Concrete

The intention of this work is to fill and seal the cracks, particularly those found on concrete bridges. The extent of the cracks shall be indicated by the Contractor and shown on the drawings, as stated in the Bridge Inspection Manual of BMS. Detail of the quantities shall be marked out on the concrete elements, and confirmed by the designated Engineer prior to epoxy application The Engineer may adjust the extent of the work as the project proceeds, based on actual conditions.

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

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

(2) Pipe Fitting Adhesion

The pipe fittings shall be fixed at intervals along the length of each crack. The distance between each fitting shall be as shown on the drawings, considering the width and depth of crack, for approval of the Engineer. The surface sealant shall be moisture tolerant putty with good adhesion to concrete. This is supplied in two components namely, the base resin and the hardener. These are weighed according to the specified mix proportions of the manufacturer. Mixed process is continued until a uniform paste is obtained.

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

(3) Epoxy Injection

Each crack shall be treated in a single, continuous operation. Sufficient materials shall therefore be readily available prior to the commencement of work. The preparation, mixing and application of the materials shall be undertaken in strict compliance with the manufacturer's recommendations,

Bridge Repair Method

No.1-1 Crack Repair Method (Crack Injection)

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

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

(4) Curing

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

(5) Performance Test

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

6. Measurement and Payment

6.1 Method of Measurement

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

6.2 Basis of Payment

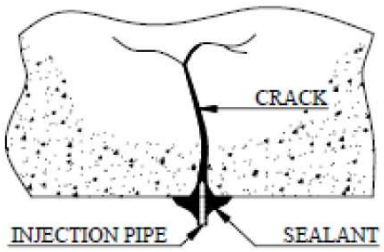
The contract price paid per meter for this work item should include full compensation for supplying all labor, materials, tools, equipment, and incidentals in performing all the works involving the preparation and injection of epoxy on cracks, completely in place, as shown on the plans and as specified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

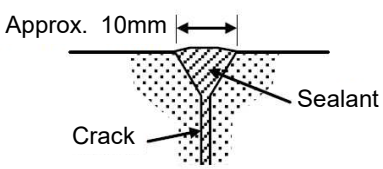
Bridge Repair Method

No.1-2 Crack Repair Method (Crack Filling)

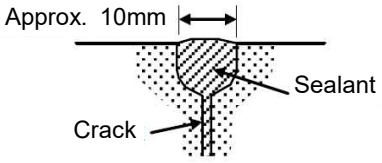
1. Description of Repair Method

Active cracks are treated and repaired with flexible sealants as shown in Figure AP 1.2.1. 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.





V-Type



U-Type

Figure AP 1.2.1 Type of Filling

2. Application Criteria

Crack widths could be more than 3.0 mm with depth of less than 300 mm. In this case, the top surface edges should be chipped or sawn to form a V-type or U-type groove, in order to provide a caulking for inlet of gravity flow of resin into the crack by injection pump.
Cracks wider than 3.0 mm generally require epoxy based injection material (mix of epoxy and mineral filler).

3. Work Sequence

3.1 Cleaning of Cracks

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

3.2 Bonding of Fitting Pipe

Pipe fitting are bonded with the adhesive to the crack center for injecting repair material. Spacing of the pipes varies between 150mm to 500mm, 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.

Bridge Repair Method

No.1-2	Crack Repair Method (Crack Filling)

3.3 Preparation of Groove

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

3.4 Drilling Holes and Fixing the Injection Pipes

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

The groove is then completely sealed with sealant.

3.5 Curing of Injected Material

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

4. Required Materials and Tools/Equipment

4.1 Required Material

- Epoxy Grout
- Sealant

4.2 Required Tools/Equipment

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

5. Specification

Bridge Repair Method

No.1-2 Crack Repair Method (Crack Filling)

5.1 Material Specifications

1) Epoxy Grout

The epoxy grout material shall be compatible with the host concrete and shall have the properties listed in Table AP 1.2.1. The testing of materials shall be in accordance with the relevant standards or equivalent ASTM Specifications.

Table AP 1.2.1 Specifications of Epoxy-Based Injection Material to Girder

Property	Test Method	Unit	Specification
Viscosity	JIS K 6833/ASTM D2393	mPa-s*	≤ 1000
Pot life	-	minute	60
Specific Gravity	JIS K 7112/ASTM D792	-	1.15± 0.1
Compressive Strength	JIS K 7208/ASTM D695	N/mm^2	≥ 50
Modulus of Elasticity	JIS K 7208/ASTM D695M	N/mm^2	≥ 1000
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 40
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM D7234	N/mm^2	≥ 1.5 CF

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

2) Sealant

The epoxy-based sealant material shall be compatible with the injection material and shall have the properties listed in Table AP 1.2.2. The testing of materials shall be in accordance with the relevant standards as shown or equivalent ASTM Specification.

Table AP 1.2.2 Specifications of Epoxy-based Sealant to Girder

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

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

5.2 Construction Requirement

(1) Preparation of Concrete

The intention of this work is to fill and seal the cracks, particularly those found on concrete bridges. The extent of the cracks shall be indicated by the Contractor and shown on the drawings, as stated in the Bridge Inspection Manual of BMS. Detail of the quantities shall be marked out on the concrete elements and confirmed by the designated Engineer before epoxy application. The Engineer may adjust the extent of the work as the project proceeds based on actual conditions.

Bridge Repair Method

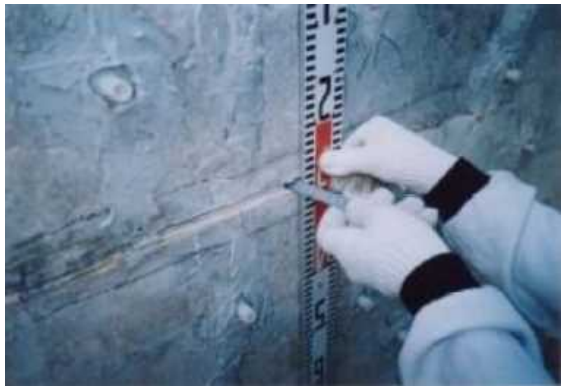
No.1-2 Crack Repair Method (Crack Filling)

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

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

(2) Preparation 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 Figure AP 1.2.1, at the surface along the crack. Clean the groove with an oil free air jet or wire brush before placing the sealant. The sealant shall be applied in accordance with the manufacturer's instructions.



(3) Drilling Holes and Fixing Injection Pipes

The injection pipes shall be fixed at intervals along the direction of each crack. The distance between each pipe shall be shown on drawings considering the width and the depth of crack, for approval by the Engineer. The sealant shall be moisture tolerant putty with good adhesion to concrete. This is supplied in two components namely, the base resin and the hardener. These are weighed according to the specified mix proportions of the manufacturer. Mixing is continued until a uniform paste is obtained.

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

(4) Grout Injection

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

The grout material shall be selected in consideration with the crack movement which should be calculated taking into account the applied loads, shrinkage and temperature variations. The Contactor shall propose suitable grout material based on the study on the crack movement, subject to Engineer’s

Bridge Repair Method

No.1-2 Crack Repair Method (Crack Filling)

approval.

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

The injection resin shall be of a pre-packed type and only the use of full units will be allowed. No partial packs or on-site batching will be allowed under any circumstances. In all operations of storage, mixing and application, the Contractor shall comply with the health and safety recommendations of the Engineer and the relevant regulations.

(5) Curing

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

(6) Performance Test

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

6. 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.

Bridge Repair Method

No.1-3	Section Repair Method (Hand applied Mortar (A) & (B))

1. Description of Repair Method

Patch repair is performed to restore small areas where concrete is damaged by spalling, scaling and impact. This method of repair is generally applied using trowel and require none or minimum formworks. The patch thickness is limited to a maximum of 100 mm depth of hollow surface. Type A Patching is for used for defects without exposed rebar while Type B Patching is applied to surfaces with exposed rebar. Patch repairs may be composed of Portland cement mortars or non-shrinkage cement mortar, depending on the type of patching, location and extent of damage.

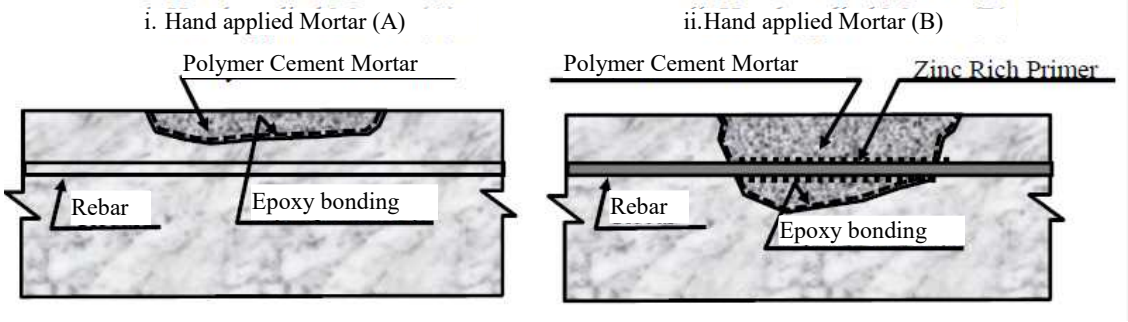


Figure AP 1.3.1 Hand applied Mortar

2. Application Criteria

Patch repair is classified into two types as shown in Figure AP 1.3.1, considering defective area and surface. Type-A is applicable to surfaces without exposed rebar, having defective widths of up to 300mm and depths of up to 50 mm. Meanwhile, Type B is used for surfaces with exposed rebar, with defective widths between 300 mm and 600 mm, and up to 100 mm depths. Portland cement mortar and polymer cement mortar is used for Type-A and Type-B patching, respectively.

3. Work Sequence

3.1 Removing Defective Concrete

Remove all defective, unsound and contaminated concrete and prepare the edges for the patch area. If local corrosion in reinforcement with section loss is found, which would require additional bars, remove only the damaged area of concrete including the length needed to bond the new reinforcement as shown in Figure AP 1.3.2.

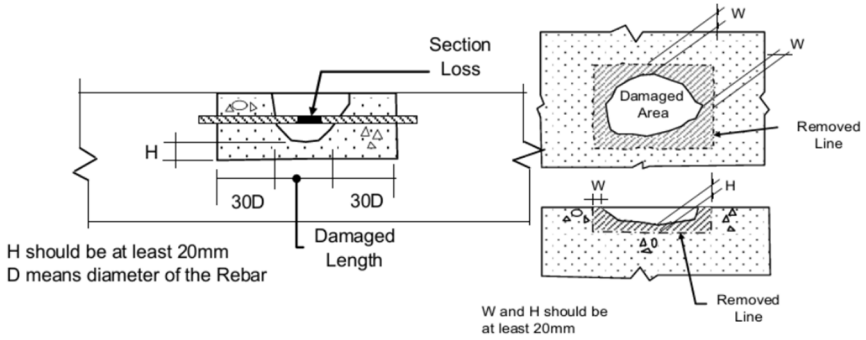


Figure AP 1.3.2 Limits of Removal of Damaged Concrete

Bridge Repair Method

No.1-3	Section Repair Method (Hand applied Mortar (A) & (B))

3.2 Cleaning of Concrete and Rebar

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

3.3 Applying Bonding Coat on the Hole and Rebars

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

3.4 Placing of Mortar

The mortar should be placed in layers of about 20 mm thick. Compact each layer thoroughly over the entire surface using a wooden trowel or hammer. Generally, there should be no time delays between the placing and compacting of layers.
Patching to the surrounding concrete is performed using a form material, and then hammered using a mallet, wood or steel trowel.

3.5 Curing Mortar

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

4. Required Materials and Tools/Equipment

4.1 Required Material

Hand applied Mortar (A):

- Polymer Cement

Bridge Repair Method

No.1-3	Section Repair Method (Hand applied Mortar (A) & (B))

- Epoxy Bonding Coat

Hand applied Mortar (B)

- Polymer Cement
- Epoxy Bonding Coat
- Zinc Rich Primer

4.2 Required Tools/Equipment

- Power Disc Grinder/Cutter
- Portable Generator
- Brush

5. Specification

5.1 Material Specifications

1) Polymer Cement

Polymer cement mortar shall conform to the requirements of the specifications shown in Table AP 1.3.1 or equivalent ASTM Specifications.

Table AP 1.3.1 Specifications of Polymer Cement

Property	Test Method	Unit	Specification
Thermal Expansion	ASTM C531	mm/mm°C	2.0×10^{-5}
Slant Shear Bond to Concrete	ASTM C882	N/mm^2	1.5 /above
Compressive Strength (7 days x 20°C)	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 AP 1.3.2.

Table AP 1.3.2 Specifications of Corrosion Protective Coating to Rebar

Property	Test Method	Unit	Specification
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 AP 1.3.3.

Bridge Repair Method

No.1-3 Section Repair Method (Hand applied Mortar (A) & (B))

Table AP 1.3.3 Specifications of Zinc Rich Primer to Rebar

Property	Test Method	Unit	Specification
Gloss at 60° Angle	ASTM D523	-	Flat
Adhesion	ASTM D3359	-	Minimum 3A
Salt Spray Resistance	ASTM D3-37	-	Excellent
%Zinc by Weight in Dried Film Test	-	%	87.5 ± 2

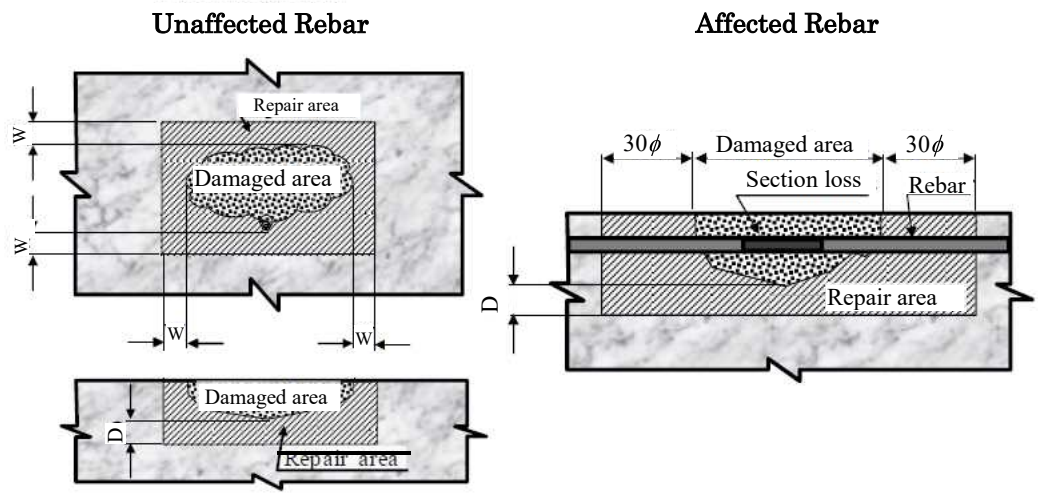
5.2 Construction Requirement

(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 AP 1.3.3.

Removal of defective concrete



Note: W and D shall be at least 20mm

Figure AP 1.3.3 Preparation of concrete surface for Hand applied Mortar

(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

Bridge Repair Method

No.1-3	Section Repair Method (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.

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 Coat

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.

(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.

Filling up in Patching

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

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

The mixing liquid shall be added to the dry components and thoroughly mixed to achieve a uniform

Bridge Repair Method

No.1-3 Section Repair Method (Hand applied Mortar (A) & (B))

consistency, unless otherwise approved by the Engineer. The mortar shall then be applied to the bonding agent using hand packing and trowel to the satisfaction of the Engineer. The textured finish of the final repair mortar layer shall match the finish on the existing interior surface.

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

(7) Curing

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

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

Curing after Patching

6. 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 contract 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, tools, equipment. It shall also include construction and removal of formworks and other temporary works necessary to complete the patching works.

Bridge Repair Method

No.1-4	Section Repair Method (Spray applied Mortar)

1. Description of Repair Method

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 AP 1.4.1). 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.

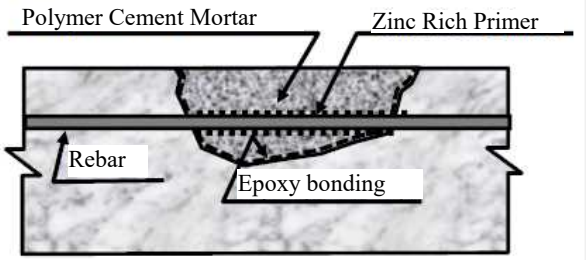
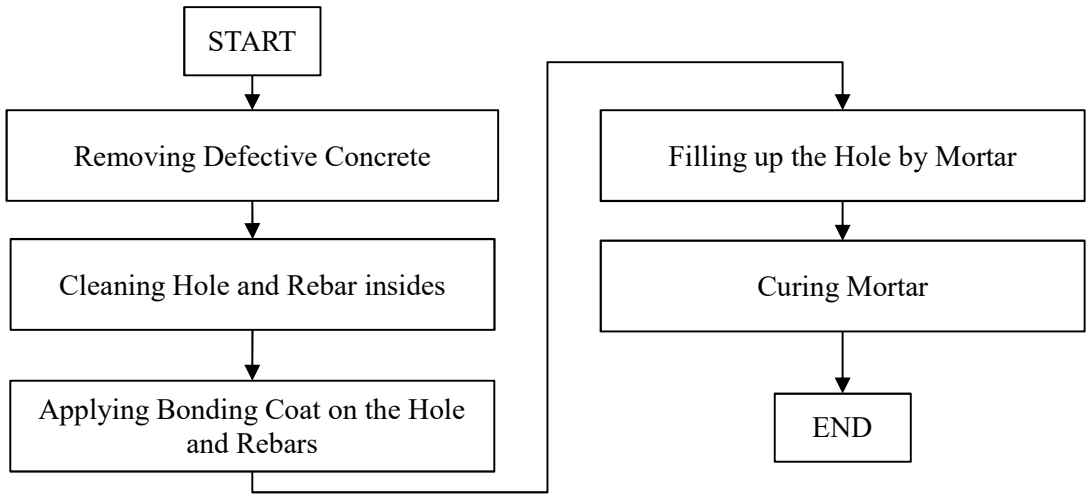


Figure AP 1.4.1 Hand applied Mortar

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



Bridge Repair Method

No.1-4 Section Repair Method (Spray applied Mortar)

4. Required Materials and Tools/Equipment

4.1 Required Material

- Polymer Cement
- Epoxy Bonding Coat
- Zinc Rich Primer

4.2 Required Tools/Equipment

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

5. Specification

5.1 Material Specifications

1) Polymer Cement

Polymer cement mortar shall conform to the requirements of the specifications shown in Table AP 1.4.1 or equivalent ASTM Specifications.

Table AP 1.4.1 Specifications of Polymer Cement

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

2) Corrosion Protective Coating

The Protective Coating of rebar shall conform to the requirements of the specifications in Table AP 1.4.2.

Table AP 1.4.2 Specifications of Corrosion Protective Coating to Rebar

Property	Test Method	Unit	Specification
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 AP 1.4 3.

Bridge Repair Method

No.1-4 Section Repair Method (Spray applied Mortar)

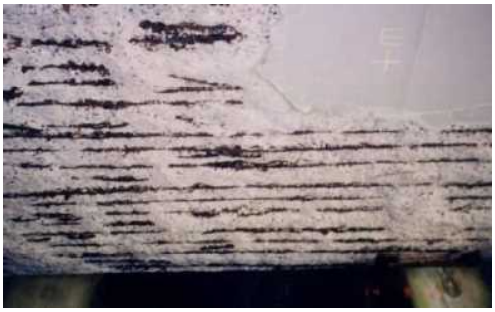
Table AP 1.4 3 Specifications of Zinc Rich Primer to Rebar

Property	Test Method	Unit	Specification
Gloss at 60° Angle	ASTM D523	-	Flat
Adhesion	ASTM D3359	-	Minimum 3A
Salt Spray Resistance	ASTM D3-37	-	Excellent
%Zinc by Weight in Dried Film Test	-	%	87.5 ± 2

5.2 Construction Requirement

(1) Removal of Defective Concrete

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.

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, 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.

Cleaning of Concrete and Rebar

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

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.

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

Bridge Repair Method

No.1-4 Section Repair Method (Spray applied Mortar)

from the Engineer, in order to remove all carbonated concrete. The additional concrete breakout shall not extend more than 20 mm behind the bottom layer main reinforcement. During breakout, utmost care shall be undertaken to minimize damage to the existing reinforcement.

(4) Additional or replacement rebar

Additional epoxy coated 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.

(5) Bonding Coating to Concrete and Rebar

Epoxy Bonding Coat

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.

(6) Spraying Repair Material

Spraying Repair Mortar

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.

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

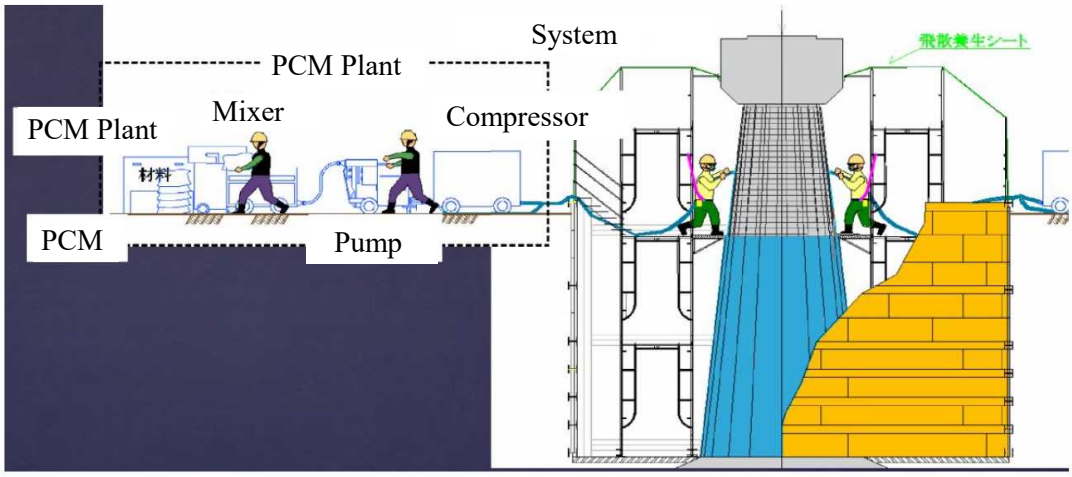
The repair mortar application shall be built up to the original surface profile in layers not exceeding 20 mm and the final layer shall not exceed 15 mm, unless otherwise recommended by the

Bridge Repair Method

No.1-4 Section Repair Method (Spray applied Mortar)

manufacturer and approved by the Engineer.

Spraying repair mortar system



(7) Curing

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

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

Curing after Spraying

6. 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 contract 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, tools, equipment. It shall also include construction and removal of formworks and other temporary works necessary to complete the spray works.

Bridge Repair Method

No.1-5 Section Repair Method (Recasting Concrete/Grout)

1. Description of Repair Method

Recasting Method, which involves casting of the damaged area, by placing concrete or grouting mortar on the formwork, is usually most suitable for severely damaged concrete, or for largely damaged areas with densely spaced rebars as shown in Figure AP 1.5.1. If concrete placing by vibration is often a problem, grout and free flowing self-compacting concrete should be developed to minimize the vibration required.

Figure AP 1.5.1 Damaged Pier for Repair by Recasting

2. Application Criteria

Recasting Concrete/Grout is divided into two methods namely: concrete placing and mortar grouting types. The mortar grouting type shall be applied Portland cement grout.

Considering the position and scale of damage, applications of the recasting concrete and grout are classified according to the formwork types, such as the "Envelope Type" and "Mail Box Type," shown in Figure AP 1.5.2. Envelope type is open at the top for pouring concrete while the mail box type consist of holes or slit at its side for purposes of grouting or pumping mortar. Mail box type formwork is further classified based on concrete volume, applied area and rebar arrangement as also shown in Figure AP 1.5.2, with due consideration to cost performance.

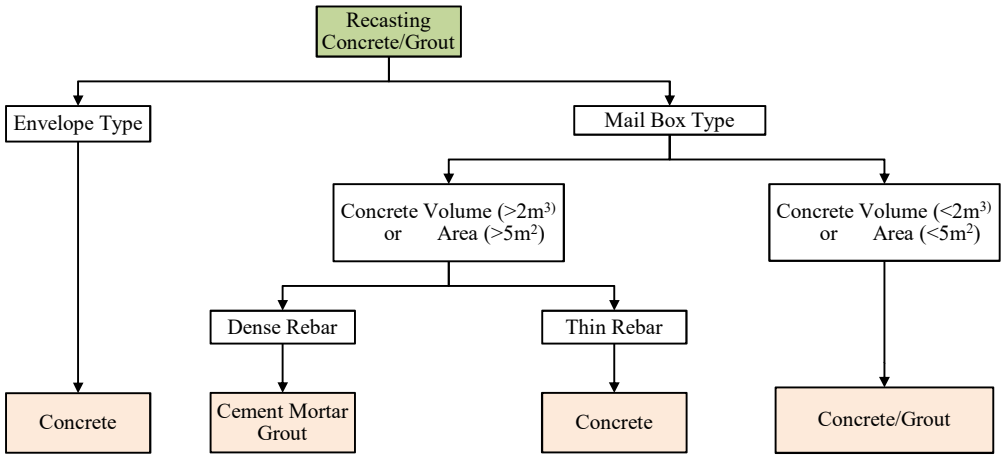


Figure AP 1.5.2 Flowchart of Selection Method for Recasting Concrete

Bridge Repair Method

No.1-5	Section Repair Method (Recasting Concrete/Grout)

3. Work Sequence

3.1 Removal of Damaged Concrete

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

3.2 Preparation of Old Concrete and Rebar

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

3.3 Cutting Existing Rebar and Adding New Rebar

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

3.4 Setting Formworks

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

3.5 Mixing Mortar

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

Bridge Repair Method

No.1-5	Section Repair Method (Recasting Concrete/Grout)

3.6 Mortar Placing

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

3.7 Curing and Removal of Formworks

Continuous water curing by spraying water is always preferable as membrane cure, which helps slow down drying process.

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

4. Required Materials and Tools/Equipment

4.1 Required Material

For Concrete

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

For Mortar

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

4.2 Required Tools/Equipment

- Sawing Equipment
- High Pressure Water Blasting

Bridge Repair Method

No.1-5 Section Repair Method (Recasting Concrete/Grout)

- Handy Concrete Breaker or Jackhammer
- Handy power Chisel
- Concrete Mixer 30 liters
- Mortar Mixer with Pump (for mortar)
- Vibrator
- Troweling tools

5. Specification

5.1 Material Specifications

1) Concrete Mixture

The mixture of concrete for recasting is guided below as reference. These quantities will make about 0.03 cubic meter of concrete and would be fully accommodated in a small mixer.

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

b) 10mm Crushed Aggregate 36.0 kg

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

d) Water (maximum) 5.4 liters

e) Super plasticizer (nominal) 25ml

The actual mix portion shall be determined during a field mixture test and approved by the Engineer.

2) Epoxy Bonding Primer

The epoxy bonding primer to concrete shall conform to the specifications in Table AP 1.5.1. The material shall be approved by the Engineer through mill certificate of the supplier.

Table AP 1.5.1 Specifications of Bonding Primer to Concrete for Recasting

Property	Test Method	Unit	Specification
Compressive Strength	JIS K 7208/ASTM D695M	N/mm^2	75
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	40
Tensile Strength	JIS K 7113/ASTM D638M	N/mm^2	30
Tensile Shear Bond to Steel	JIS K 6850/ASTM D1002	N/mm^2	10
Slant Shear Bond to Mortar	JIS K 6852/ASTM C882	N/mm^2	15

3) Zinc Rich Primer

The zinc rich primer to be applied to rebar shall be in accordance with the specifications in Table AP 1.5.2. The material shall be approved by the Engineer through mill certificate of the supplier.

Bridge Repair Method

No.1-5 Section Repair Method (Recasting Concrete/Grout)

Table AP 1.5.2 Specifications of Zinc Rich Primer to Rebar for Recasting

Property	Test Method	Unit	Specification
Gloss at 60° Angle	ASTM D523	-	Flat
Adhesion	ASTM D3359	-	Minimum 3A
Salt Spray Resistance	ASTM D3-37	-	Excellent
%Zinc by Weight in Dried Film Test	-	%	87.5 ± 2

5.2 Construction Requirement

(1) Removal of Damaged Concrete

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

(2) Preparation of Concrete and Rebar Surface

The concrete surface to which the bond coat is to be applied shall be wetted using potable water to achieve a moisture condition such that the concrete will not absorb moisture from the repair mortar. The wetting period will depend upon the substrate condition and the bond coat manufacturer's recommendations, subject to Engineer’s satisfaction. The surface shall then be left wet until the free water has evaporated before the bond coat is applied. Using a brush, the bond coat shall be applied to the exposed concrete surface and exposed reinforcement. The subsequent repair material shall be applied while the bond coat is still wet or tacky.

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

(3) Adding Rebar

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

Tying of loose bars will be required. Rebar which have been cut or have lost 25 percent or more of their original cross sectional area shall be supplemented with new reinforcement bars. New bars shall be overlapped with a minimum of 30 bar diameters to existing bars. An approved mechanical bar splice capable of developing in tension at least 125 percent of the yield strength of the existing bar shall be used when it is not feasible to provide the minimum bar overlapping.

(4) Setting Formwork

The Contractor shall submit the shop drawings of the formwork of recasting concrete prior to the commencement of the repair works for the Engineer’s approval. The formwork for re-casting repairs

Bridge Repair Method

No.1-5 | **Section Repair Method (Recasting Concrete/Grout)**

must be very rigid and well-supported to prevent the new concrete from sagging away. It shall also withstand pumping forces if concrete is to be pumped into forms. The formwork shall also withstand the forces of clamped-on external vibrators.

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

(5) Mixing and Placing Mortar

A mechanical batch mixer should be used to ensure homogeneity, workability and good board life. Clean, potable water shall be used and the maximum amount added shall be consistent with optimum workability. Hand mixing shall not be permitted unless approved in writing by the Engineer, who should outline hand mixing procedures. The finished color should not be analyzed until the addition and full mixing of the cement materials and water are complete. Uniform color requires consistent material proportioning.

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

(6) Curing and Protection

Continuous water curing by spraying water is always preferable as membrane cure, which helps slow down drying process.

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

(7) Field Test

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

6. Measurement and Payment

6.1 Method of Measurement

Recasting concrete/grout performed in accordance with the plans and specification will be measured in cubic meters. The quantity to be paid for will be the number of cubic meters of concrete replaced on the substructure and accepted by the Engineer. The measurement made for rebar shall be decided as per consultation with client

Bridge Repair Method

No.1-5	Section Repair Method (Recasting Concrete/Grout)

6.2 Basis of Payment

The quantity, measured as prescribed above, shall be paid for at the contract unit price. Removal and disposal of existing rebar and furnishing and installing new rebar will be paid for as per consultation with client. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related necessary works for supporting the substructure and scaffolding as detailed in the plans and specified herein.

Bridge Repair Method

No.1-6	Protective Coating

1. Description of Repair Method

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

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

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

Figure AP1.6.1 Protective Coating applied on Surface of Superstructure

2. Application Criteria

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

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

3. Work Sequence

3.1 Surface Preparation

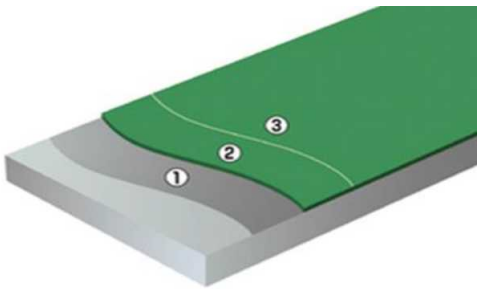
Entire surface of coating area should be cleaned by using cup wire brush and/or disc sander

Bridge Repair Method

No.1-6 Protective Coating

3.2 Mixing Acryl Urethane Protective Coating Materials

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



3.3 Application of Protective Coating

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

4. Required Materials and Tools/Equipment

4.1 Required Material

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

4.2 Required Tools/Equipment

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

5. Specification

5.1 Material Specifications

Acryl Urethane Protective Coating shall conform to specification as shown in Table AP 1.6.1 or equivalent ASTM Specifications. The material shall undergo quality tests and conform to specifications below.

Table AP 1.6.1 Specifications of Protective Coating

Property	Test Method	Unit	Specification
Bond Strength	ASTM D3359 or ASTM D7234	N/mm^2	P1.5
Tap Water Resistance	ASTM D6943	-	No change
Acid Resistance(5%H_2SO_4)	ASTM D6943	-	No change
Alkali Resistance(5%NaOH)	ASTM D6943	-	No change

5.2 Construction Requirement

Bridge Repair Method

No.1-6	Protective Coating

(1) Surface Preparation of Concrete

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

(2) Material Handling

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

(3) Application of Protective Coating

Apply 1 to 3 coats normally.

(4) Quality Control and Inspection

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

- Inspection of all materials to ensure conformity with contract requirements, and that all materials are new and undamaged.
- Inspection of all surface preparation carried out prior to protective coating application.
- Inspection of all work in progress to ensure work is being done is in accordance with Standard Specifications in Lao PDR, and approved manufacturer's instructions.
- Inspection of all work completed including verification of all repairs to the surface.

6. Measurement and Payment

6.1 Method of Measurement

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

6.2 Basis of Payment

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

Bridge Repair Method

No.1-7 Surface Treatment by Impregnation Material

1. Description of Repair Method

Purpose of the concrete surface treatment by the impregnation material is as follows;

- Control of the damages by the external factors
- Repair of the damages by the carbonation (neutralization of concrete) and the ASR (Alkali Silica Reaction)
- Prevention of re-damage after the repair

Types of this method are as follows;

- Silane Type
- Silicate Type (Lithium silicate, Sodium silicate)

Advantages of this method are as follows;

- Easy construction
- Short treatment period
- Reasonable
- Easy visual inspection after the treatment
- Decrease of the damages by UV rays

2. Application Criteria

The surface treatment by impregnation material is divided into two types, Silane Type and Silicate Type. The impregnation material shall be selected based on the following table.

Impregnation material / Damage by external factors	Silane Type	Silicate Type	
		Lithium Silicate	Sodium Silicate
Carbonation	△	△	○
ASR (Alkali Silica Reaction)	○	○	△
Repetition of dry and wet	○	-	-
Wear	-	△	△
Infiltration of water	○	-	○
Abrasion	-	△	△
Strength reduction	-	○	△

○: Applicable, △: Necessary of consideration for applicable, -: Not applicable

3. Work Sequence

3.1 Preparation of Concrete Surface

Remove the objects (oil, rust, dirt and so on) that prevent the infiltration of the impregnation materials by the blush, the high pressure water jet and the cleaning.

Bridge Repair Method

No.1-7	Surface Treatment by Impregnation Material

3.2 Surface Treatment

Perform the repair of the damaged concrete and the surface treatment (crack injection, crack filling and so on).

3.3 Curing for Protection

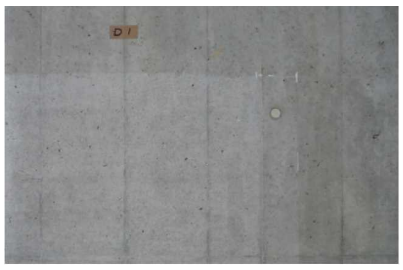
Perform the protection of out of treatment area by the curing film/sheets.

3.4 Applying Impregnation Material

- Depends on the material type, make the dry or wet condition on the concrete surface.
- Usage volume of the materials and process of treatment follow the manual of impregnation material.
- Perform treatment of the materials by the brush, the roller and the spray.

3.5 Curing

- The curing method follows the manual of impregnation material.



4. Required Materials and Tools/Equipment

4.1 Required Material

- Impregnation material (Silane Type, Silicate Type (Lithium Silicate, Sodium Silicate))
- Curing film/sheet
- Material/tool mentioning the manual of the impregnation material

4.2 Required Tools/Equipment

- Machinery for preparation of concrete surface such as the brush, the high pressure water jet
- Curing films/sheets for protection
- Paint brush/roller for applying impregnation material

Bridge Repair Method

No.1-7 Surface Treatment by Impregnation Material

5. Specification

5.1 Material Specifications

Required performance of the materials is followings and the material shall be approved by the Engineer.

Impregnation material / Cause of damage	Silane Type	Silicate Type	
		Lithium Silicate	Sodium Silicate
Carbonation depth	C	B	B
Water permeability	A	C	C
Water absorption	A	C	C
Oxygen blocking	*1		
Water vapor permeability	B	B	B
Addition of alkalinity	*1		
Abrasion resistance	*1		

Note) *1: Perform the tests and confirm the performance.

Item	Suppression Ratio (%)		
	A	B	C
Resistance for carbonation	≥ 80	80 to 60	60 ≥
Resistance for water permeability	≥ 80	80 to 60	60 ≥
Resistance for water absorption	≥ 80	80 to 60	60 ≥
Breathable	≥ 80	80 to 60	60 ≥

Bridge Repair Method

No.1-7 Surface Treatment by Impregnation Material

5.2 Construction Requirement

1) Preparation of Concrete Surface

The concrete surface condition after the preparation of concrete surface should be satisfied as follows.

Item	Criteria	Inspection Method
Appearance	To confirm the surface condition to ensure sufficient performance	Visual inspection
Damage area, efflorescence	To confirm that there are no dry out, no damage area, no efflorescence on the surface	Visual inspection/ palpation
Moisture content	To confirm that there are appropriate moisture content on the surface	

2) Surface Treatment

The concrete surface condition after the surface treatment should be satisfied as follows.

Item	Criteria	Inspection Method
Leakage	No leakage	Visual inspection
Crack	All cracks less than 0.2 mm	
Honeycomb	Properly treated the honeycombs	
Cold joint	Properly treated the cold joints	
Construction joint	Properly treated the construction joints	
Damage area	Properly treated the damage areas	Visual inspection/ palpation
Finishing	Not dirty Adhered no re-bar, no chip of wood on the surface	Visual inspection

3) Applying Impregnation Material

It is confirmed that the actual usage volume and area are equal or more than the planned volume and area. Moreover water is sprinkled and confirm the condition of water repellency.

6. Measurement and Payment

6.1 Method of Measurement

Surface treatment by impregnation material 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 surface treatment by impregnation material, as specified on plans and specifications, and as directed by the engineer.

Bridge Repair Method

No.1-8 Peeling Prevention Method

1. Description of Repair Method

This method prevents the concrete cover pieces from falling due to the deformation of the concrete, which is to impart the peeling prevention performance to the concrete surface by attaching a continuous fiber sheet with an adhesive. Since peeling of concrete pieces may cause damage to a third party, its use is mainly considered for structures concerned about damage to a third party. There are sheet type and coating film types in this method, but the sheet type is shown in this section.

2. Application Criteria

In order to carry out this method, it is necessary to appropriately carry out pretreatment such as removing deformed parts of existing structures, surface treatment, and chipping treatment. As the pretreatment method, it is desirable to apply the water-jet method for the following reasons.

- Removal of the deformed part requires finding floating/peeling and reliable/appropriate removal of the part. However, an inspection by an inspector using an inspection hammer cannot precisely inspect the entire area of the structure as a countermeasure against peeling. On the other hand, if the treatment is carried out by the water-jet method in which an appropriate water pressure, amount of water are set, it can be reliably removed.
- When the surface is treated by the water-jet method with appropriate water pressure and amount of water, it is possible to obtain a treated surface that can secure the integrated properties of the old and new members equal to or higher than the blast method.
- When the chipping treatment is performed, vibration or impact from the impact breaker may adversely affect the chipping treatment surface, which is the adhesion surface of the old and new members, or damage the rebar. On the other hand, the water-jet method does not cause these problems.

3. Work Sequence

3.1 Surface Treatment

The laitance on the concrete surface is removed with tools such as disc-sander, and the surface is roughened. After surface treatment, the dust adhering is removed from the surface. If the concrete surface is uneven due to the seams of the formwork, it should be repaired with repair material of cross-sectional method or epoxy putty.

3.2 Surface Coating (Undercoat Material Application)

The main agent and the curing agent are agitated and mixed with an agitator for about 2 minutes. The mixed primer is applied to the concrete surface with a roller. The agitator should be screw-shaped and low-speed, and the coating should be agitated so as not to entrain air.

Bridge Repair Method

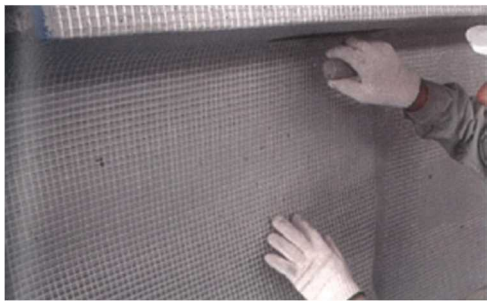
No.1-8 Peeling Prevention Method

3.3 Surface Coating (Intermediate Coating Material No.1 Application)

After the undercoat material is dried, the intermediate coating material No.1 is applied with a roller. If this is left for a long time, solid matter tends to settle, so it is necessary to expand sales uniformly. The agitator should be a low-speed one with the blades rotating, and the intermediate coating material should be agitated so as not to entrain air.

3.4 Surface Coating (Pasting the Reinforcing Sheet)

After applying the intermediate coating material No.1, the reinforcing sheet is pressed by a trowel, rubber spatula, roller, and pasted to the construction surface.

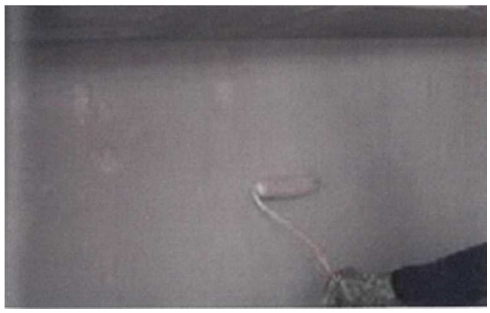


3.5 Surface Coating (Intermediate Coating Material No.2 Application)

After attaching the reinforcing sheet, the intermediate coating material No.2 is applied with a trowel. If this is left for a long time, solid matter tends to settle, so it is necessary to expand sales uniformly. The agitator should be a low-speed one with the blades rotating, and the intermediate coating material should be agitated so as not to entrain air.

3.6 Surface Coating (Topcoat Material Application)

The main agent and the curing agent are agitated and mixed with an agitator for about 2 minutes. The agitator should be a low-speed one with the blades rotating, and the topcoat material should be agitated so as not to entrain air. After the intermediate coating material No.2 is dried, the topcoat material is applied with a roller.



4. Required Materials and Tools/Equipment

4.1 Required Material

- Epoxy Resin for Primer
- Chloroprene Rubber for Intermediate Material No.1, No.2
- High-Strength Polyethylene Biaxial Sheet for Reinforcing Sheet
- Hindered Amine Light Stabilizer (HALS) Hybrid Resin for Topcoat Material

Bridge Repair Method

No.1-8 Peeling Prevention Method

4.2 Required Tools/Equipment

- Water-Jet
- Blast Machine
- Disc Sander
- Air Compressor
- Agitator

5. Specification

5.1 Material Specifications

(1) Epoxy Resin for Injection

The material used to prevent peeling must have the performance of 1) to 3).

1) Peeling prevention performance

Performance to prevent concrete pieces from falling due to peeling

Check Item	Criteria	Test method
Punching test to prevent peeling	More than 1.5kN	JSCE-K 533

2) Crack impregnation performance of primer

Performance to penetrate cracks that are difficult to be injected into on existing structures

Check Item	Criteria	Test method
Crack impregnation test	More than 2.0N/mm2	NEXCO test method 426

3) Durability

Performance that maintains the performance of 1) and 2) after preventing that deterioration factors that promote corrosion of steel materials from penetrating the concrete

Check Item		Criteria	Test method
Crack impregnation test	Adhesive strength	Punching test criteria "1.5kN" ≤ Minimum value of punching test result multiplied by minimum retention rate (%)	NEXCO test method 425
	Crack resistance		

5.2 Construction Requirement

(1) Construction Management

The work should be taken into account the weather conditions.

(2) Quality Control

1) Coating Thickness

- Objective coating thickness: 410 μm (Intermediate material No.1, No.2, and Topcoat)
- The coating thickness control for each layer is omitted because the thickness change caused by the volatilization of the solvent is in progress.

Bridge Repair Method

No.1-8 Peeling Prevention Method

- The coating thickness should be controlled without the reinforcing sheet in order to prevent the variation of the measured value.

a. Measurement frequency: decided as per consultation with a client

b. Standard value:

- The average value of coating thickness of rod: more than ninety percent out of the objective coating thickness
- The minimum value of coating thickness of rod: more than seventy percent out of objective coating thickness
- Standard deviation: less than twenty percent out of objective coating thickness

2) Appearance
   - Inspection criteria: there is no swelling or peeling part by visual inspection entirely

3) Adhesive Strength

a. Inspection criteria: more than 1.5N/mm2

b. Inspection method: one test piece per one site, and calculation of the average of measurement value at any three places

c. Inspection period: 28 days later principally after completion of coating

6. Measurement and Payment

6.1 Method of Measurement

The payment for peeling prevention works on cracks shall be based on the total coating area, as proposed by the Engineer.

6.2 Basis of Payment

The contract price paid per square meter for this work item should include full compensation for supplying all labor, materials, tools, equipment, and incidentals in performing all the works involving the preparation and coating of peeling prevention materials, completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer

Bridge Repair Method

No.1-9	Regrouting Method

1. Description of Repair Method

This method is to refill the grout, when the prestressed concrete grout of the inner cable is insufficiently filled, to prevent rust and restore the function of adhesion. Prestressing tendon is an important material that constitutes a prestressed concrete structure. Therefore, in repairs, it is important not only to recover the initial performance but also to ensure durability to satisfy the functions required for the prestressed concrete structure over the planned remaining service life.

2. Application Criteria

In order to apply this method, it is essential to confirm the underfilled section by appropriate surveys such as the X-ray transmission method. A regrout plan will be formulated based on this survey results. Therefore, it shall not be applied if there is no survey result and a regrout plan can not be formulated.

3. Work Sequence

3.1 Pretreatment for Grouting (Survey for Unfilled Parts)

Non-destructive inspection (X-ray transmission method, tapping vibration method) or direct inspection method (chipping method, drilling method) confirms the presence or absence of unfilled grout and its position.

3.2 Pretreatment for Grouting (Drilling and Installing pipe)

Drilling is performed with a diameter of about 20 mm, and the drill tip stops in front of the sheath. After drilling, it is desirable to check the corrosion condition of the prestressing tendon with a CCD camera.

3.3 Pretreatment for Grouting (Ventilation Check)

In order to confirm the unfilled part of the grout, the ventilation is confirmed using all the holes drilled. In principle, ventilation confirmation is performed using compressed air or water. If there are some leakage points, they should be repaied by sealing with appropriate material such as jet-cement.

3.4 Grouting

Grout is injected from the lower part of the sheath to the higher. The injection work is carried out using a manual pump, paying attention to material leakage. When the injected material is discharged from the discharge hole, close the discharge hole. After the injection pressure becomes 0.5 MPa, if it does not decrease even after being left for one minute, the injection hole is closed.

3.5 Inspection

After grouting, the inside of the sheath should be reconfirmed with the X-ray and inspected if the defective part is completely filled with grout.

3.6 Post-treatment of Grouting

The injection hole and the discharge hole are cut with tools such as a sander. Moreover, their surface should be treated to prevent unevenness with the concrete surface.

Bridge Repair Method

No.1-9 Regrouting Method

4. Required Materials and Tools/Equipment

4.1 Required Material

Grouting material is applied from below

- Cement type: Ultrafine Cement
- Non-cement type: Epoxy Resin

4.2 Required Tools/Equipment

- Hummer Drill
- Vacuum Pump
- Grout Pump
- Mixer

5. Specification

5.1 Material Specifications

1) Epoxy Resin for Grouting

Epoxy resin should be compatible with the host concrete and should have the properties listed in Table AP 1.9.1. Testing of materials shall be in accordance with the relevant standards or equivalent ASTM specifications.

Table AP 1.9.1 Specifications of Epoxy Resin for Injection to Superstructure

Property	Test Method	Unit	Specification
Viscosity	JIS K 6833/ASTM D2393	mPa-s*	≤ 1000
Pot life	-	Minute	60
Specific Gravity	JIS K 7112/ASTM D792	-	1.15± 0.1
Compressive Strength	JIS K 7208/ASTM D695	N/mm^2	≥50
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥40
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥10
Slant Shear Bond Strength to Concrete	JIS K6852/ASTM C882	N/mm^2	15/above
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM D7234	N/mm^2	≥1.5 CF

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

5.2 Construction Requirement

(1) Pretreatment for Grouting

The inside of the hole is thoroughly cleaned not to leave dust, and the injection pipe and discharge pipe are installed.

(2) Grouting

Bridge Repair Method

No.1-9	Regrouting Method

If the grout is not discharged from the discharge hole, the injection pressure is raised to 0.5 MPa and left as it is for about one minute. If this pressure decreases, the same procedure should be carried out again. Regardless of that, if there is no change in the injection pressure, it is impossible to continue the grouting work. If the grouting is impossible, it should be performed from the discharge hole to the injection hole. The applicable time of grouting material is maximally for sixty minutes.

6. Measurement and Payment

6.1 Method of Measurement

The payment for regrouting works of the prestressing cable shall be based on the total length of the grouting, as identified by the Engineer.

6.2 Basis of Payment

The contract price paid per meter for this work item should include full compensation for supplying all labor, materials, tools, equipment, and incidentals in performing all the works involving the preparation and grouting, completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer

Bridge Repair Method

No.1-10	Waterproofing

1. Description of Repair Method

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

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

On the other hand, liquid system involves a simple procedure similar to painting method. Many skilled workers in the Philippines are qualified and experienced in utilizing this system. In this repair manual, two types of liquid system are introduced, namely, Rubberized Membrane Type (Figure AP 1.10.1) and Asphalt Compound Membrane Type (Figure AP 1.10.2).

Figure AP 1.10.1 Rubberized Membrane Type

Figure AP 1.10.2 Asphalt Compound Membrane Type

2. Application Criteria

The rubberized type waterproof membrane mainly consists of chloroprene rubber. The asphalt compound type meanwhile consists of asphalt mixed with special rubber, which is melted in a mechanically agitated heating process. (See Figure AP 1.10.3)

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

The second system involves less costly materials. However, equipment costs such as kettle and

Bridge Repair Method

No.1-10	Waterproofing

heating tool, including its inland transport cost tends to somehow increase related construction cost. In this manual, the second system is recommended considering ease of application and low cost as well as its good performance.

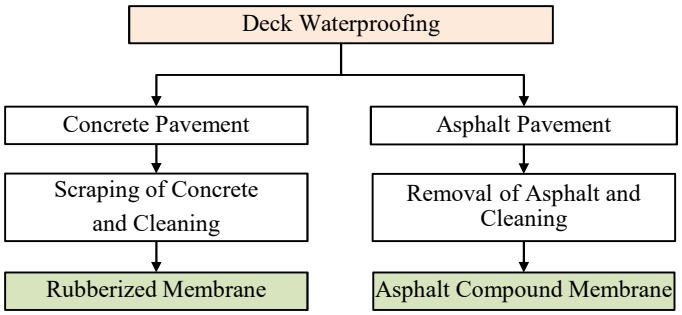


Figure AP 1.10.3 Flowchart for Selection of Waterproofing

3. Work Sequence

3.1. Rubberized Membrane

Rubberized Membrane is composed as shown in Figure AP 1.10.4.

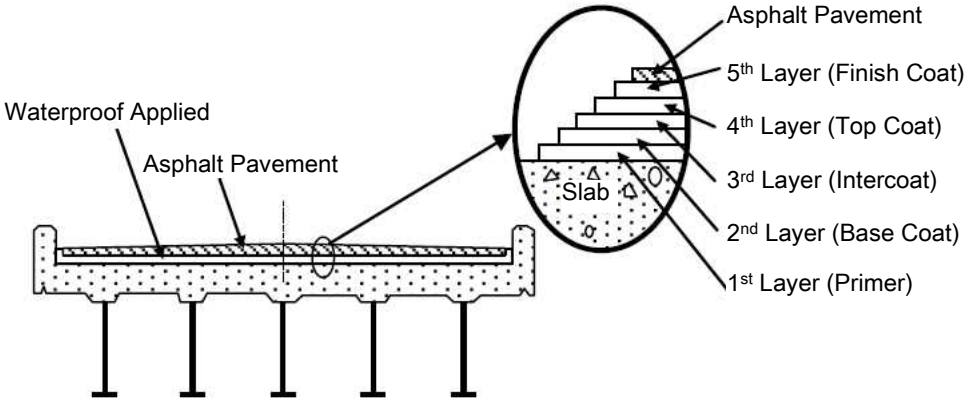


Figure AP 1.10.4 Composition of Layer of Rubberized Membrane

(1) Deck Surface Preparation

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

Bridge Repair Method

No.1-10	Waterproofing

(2) 1st Layer (Primer)

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

(3) 2nd Layer (Base Coat)

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

(4) 3rd Layer (Intercoat)

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

(5) 4th Layer (Top Coat)

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

(6) 5th Layer (Tack Coat)

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

(7) Asphalt Pavement

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

Bridge Repair Method

No.1-10	Waterproofing

3.2. Asphalt Compound Membrane

Asphalt Compound membrane is composed of layers as shown in Figure AP 1.10.5.

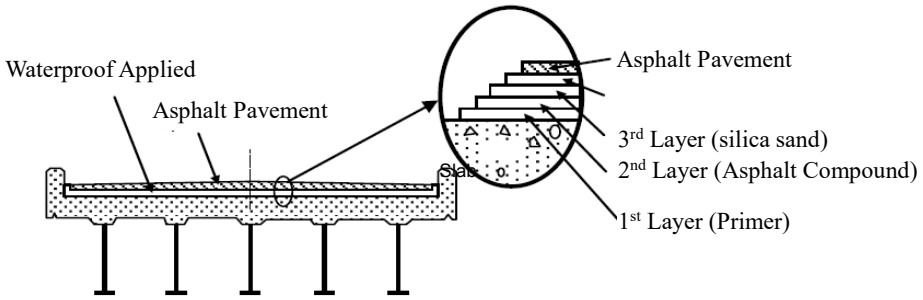


Figure AP 1.10.5 Composition of Layer for Asphalt Compound Membrane

(1) Preparation of Surface

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

(2) Primer Coating

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

(3) Melting Asphalt Compound

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

(4) Application of Asphalt Compound

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

Bridge Repair Method

No.1-10	Waterproofing

(5) Application of Silica Sand for Protection

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

(6) Curing/Asphalt Pavement

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

4. Required Materials and Tools/Equipment

4.1 Required Material

(1) Rubberized Membrane

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

(2) Asphalt Compound Membrane

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

4.2 Required Tools/Equipment

(1) Rubberized Membrane

- Paint Roller

(2) Asphalt Compound Membrane

- Kettle with heater
- Roller brush or hair brush
- Rubber brush

5. Specification

Bridge Repair Method

No.1-10	Waterproofing

5.1 Material Specifications

(1) Rubberized Membrane

Waterproofing by rubberized membrane shall conform to the requirements of the Specifications as shown in Table AP 1.10.1 or equivalent ASTM Specifications. The material shall be approved by the Engineer through mill certificate of the supplier.

Table AP 1.10.1 Specifications of Rubberized Membrane

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

(2) Asphalt Compound Membrane

Primer

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

Waterproofing by asphalt compound membrane shall conform to the requirements of the specifications shown in Table AP 1.10.2, or equivalent ASTM Specification. The material shall be approved by the Engineer through mill certificate of the supplier.

Table AP 1.10.2 Specifications of Asphalt Compound for Waterproofing

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

5.2 Construction Requirement

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

(1) Rubberized Membrane

Surface Preparation

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

Primer Coating

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

Bridge Repair Method	
No.1-10	**Waterproofing**

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

Application of Rubberized Membrane

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

Application of Tack Coating

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

(2) Asphalt Compound Membrane

Surface Preparation

The deck concrete, including curbs, and sidewalks must be completely dry and cured at least 14 days before application of primer or membrane. The existing surface of concrete shall be completely sandblasted or shot wire brush to expose sound, laitance-free concrete. All dirt and debris shall be removed and disposed of, leaving a prepared surface satisfactory for primer coating. Primer coating and waterproofing shall not commence until the Engineer has accepted all preparation works. If the existing asphalt pavement is covered on the deck slab, the pavement shall be stripped-off totally using pavement scraper.

Immediately prior to the application of the primer coat, the concrete surface shall be air blasted to remove all dust and any other foreign materials. Primer coat material shall be applied with approved equipment which will provide uniform application at the required rate. The primer coat shall be applied only when the concrete is dry and clean, and when the air and concrete surface temperatures are above 10ºC. Waterproofing equipment or material shall not be permitted on the primer coat until it has fully cured and is completely tack-free.

Melting Asphalt Compound

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

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

Application of Asphalt Compound

Asphalt Membrane shall not be applied until the primer has cured completely. The asphalt membrane shall be applied within the temperature range recommended by the Manufacturer, to the clean, primer-coated concrete deck, to form a uniform film having a minimum thickness of 4 mm ~ 6 mm (Approximately 1.2kg/m^2). The laying operation shall be such that discontinuities in the membrane are avoided and any joints lapped 150 mm. The membrane shall be applied over all the waterproofed joints and cracks, and shall extend up to the face of curbs, medians, barrier walls, and deck drains, to

Bridge Repair Method	
No.1-10	**Waterproofing**

the height of the top of the hot mix surface course. Deck drains and drainage tubes shall be covered.

Application of Silica Sand for Protection

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

6. Measurement and Payment

6.1 Method of Measurement

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

6.2 Basis of Payment

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

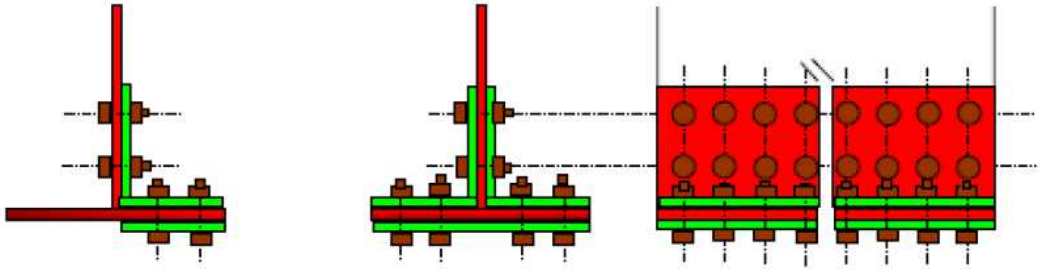
Bridge Repair Method

No.1-11	Steel Plate Bonding

1. Description of Repair Method

Steel girders near sea shores are prone to corrosion which could accelerate, consequently leading to section loss, especially of the bottom flange plates and sections near the bearings.

There were incidences where existing steel bridges near sea shores were not maintained for around 20 years. Severe corrosion had occurred causing significant section loss and defective bolt holes. In such cases, strength of the lower flange section shall be restored considering the original designed area. This is implemented by adding steel plates or angles connected with high tension bolts (HTB) as shown in Figure AP 1.11.1.



(1) One side of lower flange (2) Two sides of lower

Figure AP 1.11.1 Asphalt Compound Membrane Type

Existing bottom flanges with section loss shall be provided with a flat plate at its bottom face, bolted with HTB to angular (bent plates) placed at the junction of web and bottom flange. The suggested total thickness of the plates shall be approximately 9 mm.

2. Application Criteria

In order to restore the lost strength, additional steel plates shall be installed to the portion of existing steel, where section loss is more than 20%. This repair method shall be further supplemented by repainting or special anti-corrosion coating.

3. Work Sequence

3.1. Scaffoldings

Scaffolding for safe and efficient repainting works shall be provided. Chain or wire ropes shall be attached to bottom flanges or stiffeners to tie the supporting timber or steel pipes, which serve as framing for the wooden planks.

3.2. Surface Preparation

All surfaces to be provided with additional steel plates shall be thoroughly cleaned of all rust, dirt, oil or grease, and other foreign substances. Moreover, surfaces to be painted shall be lightly grinded to increase adhesion of the new paint required. The grade of surface preparation shall conform to No.12 Repainting or shall be as recommended by the manufacturer.

Bridge Repair Method

No.1-11	Steel Plate Bonding

3.3. Surface Treatment

Surfaces of corroded steel plate may have holes and dents. Reduction of original thickness of the steel plate could as well vary. After surface preparation, epoxy putty is applied to level the surface of the existing steel plate and recover its original thickness and shape.

3.4. Holes for HTB

Templates for bolt holes for the additional flat plate or angular plate, which shall be fabricated at the factory, shall be prepared based on the actual positioning required at site. Holes for the HTB are drilled through the plates using portable electric drill or electric coring drill. Suggested diameter of hole is 25 mm to 27 mm, intended for M22 HTB.

3.5. Assembling Flat Plate and Angular Plate

Additional flat plates and angular plates are placed on the actual bottom flange locations for purposes of installing HTB. After installation, each HTB is first fastened with electric fastener.

3.6. Epoxy Caulking

Small gaps found between the new plate and existing steel plate shall be filled with epoxy caulking.

3.7. Tightening High Tension Bolts

After the first fastening as per 3.5 above, yellow mark is painted on each HTB in order to identify the original orientation. HTB are finally tightened using rotation angle method as means of quality control to maintain design tension stress. The limit of rotation angle for tightening shall be 120°±30° from the marking.

3.8. Painting

After installation of the steel plates and HTB are completed, polyurethane aluminum paint is applied. Portions of steel plate where section loss or severe corrosion are found shall be painted with special anti-corrosion paint as protection against further rusting.

3.9. Historical Record Marking

Historical record for the repair measure performed should be marked on the web plate near the bearing as shown in No.12 Repainting 3 (7).

4. Required Materials and Tools/Equipment

4.1 Required Material

- Flat Plate
- Angular Plate
- High Tension Bolt (HTB)
- Epoxy Putty

Bridge Repair Method

No.1-11	Steel Plate Bonding

4.2 Required Tools/Equipment

- Electric Drill
- Fastening wrench

5. Specification

5.1 Material Specifications

Specifications for related materials for this repair method are as follows:

- Flat/Angular plates (JIS G3101, 3106, ASTM A36 or equivalent)
- HTB (JIS B 1186, ASTM A325 or equivalent)
- Polyurethane Aluminum Paint (refer to No.12 Repainting).
- Epoxy putty

Table AP 1.11.1 Specifications of Epoxy Adhesive

Property	Test Method	Unit	Specification
Specific Gravity	JIS K7112/ASTM D792		1.7±0.20
Flexural Strength	JIS K7203/ASTM D790M	N/mm2	≥ 40
Compressive Strength	JIS K7208/ASTM D695M	N/mm2	≥ 70
Modulus of Elasticity	JIS K7208/ASTM D695M	N/mm2	≥ 4000
Tensile Strength	JIS K 7113/ASTM D638M	N/mm2	≥ 25
Tensile Shear Bond	JIS K 6850/ASTM D1002	N/mm2	≥ 10
Bond Strength to CFP &Concrete	JIS K5400/ ASTM D7234	N/mm2	≥ 3.5

The type of test shall be applied tensile strength test for HTB to be approved by the Engineer.

5.2 Construction Requirement

(1) Surface Preparation

The Engineer will instruct the Contractor on the required grade of surface preparation. Regardless of the severity of corrosion, section loss to be mainly considered shall be limited to the bottom flange and edges of girders near the bearings. The contractor shall submit related shop drawings for Engineer's approval.

(2) Material Handling

Templates for bolt holes shall be provided for the steel plates fabricated at the factory, based on required actual positioning at site.

Prior to fabrication, the contractor should submit shop drawings for Engineer's approval.

(3) Epoxy Putty

This work item for achieving smooth surface between steel plates is optional.

Bridge Repair Method	
No.1-11	**Steel Plate Bonding**

- Mix two parts of epoxy putty until the mixture is homogenized.
- Apply the putty to smoothen the gap between the steel plates

(4) Holes for HTB

Holes for the HTB are drilled through the steel plates using portable electric drill or electric coring drill. Suggested diameter of hole is 25 mm to 27 mm, intended for M22 HTB.

6. Measurement and Payment

6.1 Method of Measurement

Method of measurement for this repair method shall be the total weight of the steel plates and HTB, verified and approved by the Engineer.

6.2 Basis of Payment

Payment shall be based on unit price per kg. The unit price shall include all materials, containers, equipment, tools, labor, service advisor, and incidental items for these works. Any indirect cost item shall not be paid separately. Such costs shall be deemed included in the per kg price.

Bridge Repair Method

No.1-12	Repainting

1. Description of Repair Method

The service life of steel bridges could be expected to exceed 50 years if its surface is kept in good protection using suitable paint coating. However, if corrosion occurs, repainting is the only restoration and effective method for steel structures. Before repainting, the surface, should at first be washed with fresh water to remove any salt from sea water environment. Relevant surface preparation shall be applied for the corroded areas to remove rust. Preparation for steel surfaces consists of two different grades of surface treatment for repainting, depending on rust conditions and type of paint, as shown in Table AP 1.12.1.

Table AP 1.12.1 Type of Repainting

Defects	Type of Paint	Photo	Rust Condition
Repaint	Epoxy Zinc Rich Primer and Polyurethane Aluminium Paint		Corossion is very severe and coating film is not visible. 1st grade surface preparation is necesarry.
	Modified Epoxy Poluimide Paint and Polyurethane Aluminium Paint		Corossion is severe and coating film is visible but almost deteriorated due to corrosion. 2nd grade surface preparation is necessary.

The polyurethane aluminum paint shall be applied as intermediate and top coat for all steel plate surfaces.

2. Application Criteria

This repair method shall be applied when affected surface area is over 30%.

The 1st grade surface preparation shall be applied if the rust is very severe and coating film is not visible. The 2nd grade surface preparation shall be applied if the rust is severe and coating film is visible but almost deteriorated as shown in Table AP 1.12.2.

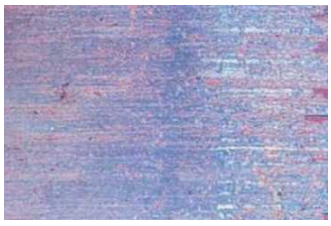
The 3rd and 4th grade surface preparation are not intended for repainting. However, these are carried out for application of special anti-corrosion paint which has strong adhesion to steel surface.

Additional primer coating shall be applied for bottom flanges, which are usually subjected to severe corrosion.

Bridge Repair Method

No.1-12	Repainting

Table AP 1.12.2 Preparation Grades of the Surface of Corroded Steel Plate

Grade	Rust Condition	Working Process	Photography (After Preparation)
1st Grade	Corrosion is very severe on steel surface and coating film is not visible due to corrosion. Affected surface area is over 30%	Old coating film, red rust and black rust are completely removed and revealed steel color with sand blasting or shot blasting.	
2nd Grade	Corrosion is severe on steel surface and coating film is visible but almost deteriorated due to corrosion. Affected surface area is over 30%	Old coating film, rust is completely removed and revealed steel color with disk grinder.	
3rd Grade	Corrosion is partially severe on steel surface and coating film is almost visible but partially deteriorated due to corrosion. Affected surface area is 20 ~ 30%	Old coating film, rust is removed and partially revealed steel color with scraper and wire brush.	
4th Grade	Corrosion is partially visible but not severe. Peel-off of Coating film is partially visible. Affected surface area is 10 ~ 20%	Old coating film, rust is removed with disk grinder, scraper and wire brush.	

3. Work Sequence

(1) Scaffoldings

Scaffoldings for safe and efficient repainting works shall be provided for the whole bridge. Chain or wire ropes shall be attached to bottom flanges or stiffeners to tie the supporting timber or steel pipes, which serve as framing for the wooden planks. If sand blasting is required, steel girder shall be covered with plastic sheet to avoid pollution impact to surrounding soil and water.

Bridge Repair Method

No.1-12	Repainting

(Scaffolding)

(Environment Protection)

(2) Preparation of Steel Surfaces

As first step, the steel bridge shall be washed with fresh water. All adhering rust, scale, dirt, grease or other foreign material shall be removed using a disc grinder or steel wire brush, depending on required surface preparation.

(3) Filling Voids

During steel surface preparation, any existing voids are filled with epoxy putty, especially if the severely corroded surface has lost significant thickness.

(4) Painting

Paint is usually applied on the steel surface using paint brush and paint roller, to ensure smooth and flat surface. It should be strictly executed to keep a continuous, uniform film of specified thickness. Paint consists of one layer of primer and two layers of polyurethane aluminum paint.

Primer

Paint (2 Layer)

Bridge Repair Method

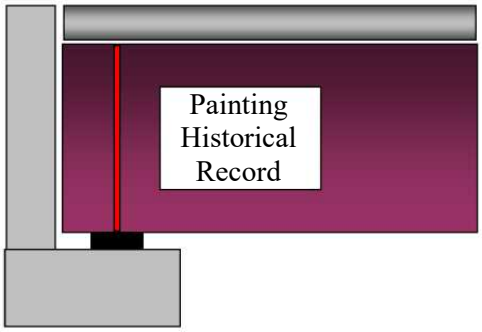
No.1-12	Repainting

(5) Checking Paint Thickness

Measure coating film thickness using Paint/Coating Thickness Meter.

(6) Historical Record Marking

It is important to mark on the bridge surface, the Painting Historical Record. This shall be marked on web plate, near the bearing, as shown in the adjacent figure.



Example of Historical Marking Record:

Date of Painting Completion		April 22,2021
Surface Preparation		2nd Grade
Paint Name	1st Coat : Primer	Modified Epoxy Polyimide Paint: Lao** GUARD** 75μ
	2nd Coat : Primer (for Lower Flange only)	Modified Epoxy Polyimide Paint: Lao** GUARD** 75μ
	3rd Coat : Middle Coat	Polyurethane Paint : Lao** MA*** 50μ
	4th Coat : Top Coat	Polyurethane Paint : Lao** MA*** 50μ
Paint Maker Company Name		Lao********* Paint***** Company
Painting Company		Lao** Paint** Works Company

4. Required Materials and Tools/Equipment

4.1 Required Material

- Epoxy Zinc-rich Primer
- Modified epoxy polyimide paint
- Polyurethane Paint
- Thinner

4.2 Required Tools/Equipment

- High-pressure water jet spray
- Water tank

Bridge Repair Method

No.1-12	Repainting

- Generator
- Disc Grinder
- Sand blast machine
- Air compressor
- Wire brush and scraper
- Paint roller and Paint brush

Sand Blast Compressor

Sand Blast Spray Gun

5. Specification

5.1 Material Specifications

The Specification of repainting for each of the two cases of surface preparation shall conform to the requirements in Table AP 1.12.3 and Table AP 1.12.4 or equivalent ASTM Specifications. The materials shall be approved by the Engineer through mill certificate of the supplier.

Table AP 1.12.3 Specifications of Repainting for 1st Grade Surface Preparation

Function	Description	DFT(μ)	Test Method	Painting Interval (hours)
Surface Preparation	Near white Blast Cleaning should be done to remove paint, rust, scale, dirt, grease or other foreign matters. Solvent cleaning by lacquer thinner to remove dirt, oil, grease and other contaminants. All surfaces to be painted must be dry and free from dust. (SSPC-SP10)			4
1st Coat: Primer	Epoxy Zinc Rich Primer (SSPC-Paint No.20)	75	ASTM D520	8
2nd Coat: Top Coat (for lower flange plate)	Epoxy Zinc Rich Primer (SSPC-Paint No.20)	75	ASTM D520	8
3rd Coat: Intermediate Coat	Polyurethane Paint (SSPC-Paint No.36)	50	ASTM D16, Type V Polyurethane	4
4th Coat: Top Coat	Polyurethane Paint (SSPC-Paint No.36)	50	ASTM D16, Type V Polyurethane	4

Bridge Repair Method

No.1-12 **Repainting**

Table AP 1.12.4 Specifications of Asphalt Compound for Waterproofing

Function	Description	DFT(μ)	Test Method	Painting Interval (hr)
Surface Preparation	Power Tool Cleaning to remove existing paint, rust, scale, stains and other foreign matters. Solvent cleaning by lacquer thinner to remove dirt, oil, grease and other contaminants. All surfaces to be painted must be dry and free from dust.(SSPC-SP10)			4
1st Coat: Primer	Modified Epoxy Polyimide Paint (SSPC-PS13.01)	75	ASTM D1652	8
2nd Coat: Top Coat (for lower flange plate)	Modified Epoxy Polyimide Paint (SSPC-PS13.01)	75	ASTM D621	8
3rd Coat: Intermediate Coat	Polyurethane Paint (SSPC-Paint No.36)	50	ASTM D16, Type V Polyurethane	4
4th Coat: Top Coat	Polyurethane Paint (SSPC-Paint No.36)	50	ASTM D16, Type V Polyurethane	4

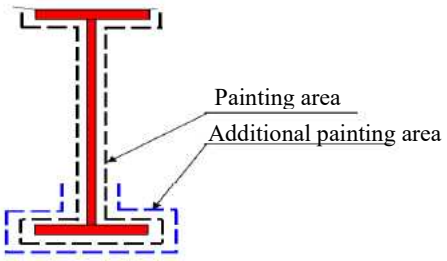


Figure AP 1.12.1 Repainting Area

5.2 Construction Requirement

(1) Preparation of Steel Surface

All surfaces to be painted shall be thoroughly cleaned of all rust, dirt, oil or grease, and other foreign substances. Additionally, paint surfaces shall be lightly sand blasted or sanded prior to painting, to enhance adhesion. The method of surface preparation shall conform to this subsection 2 or shall be as recommended by the coating manufacturer.

The contractor shall furnish and install necessary protective devices at the site of the cleaning and surface preparation to ensure complete protection of public and properties adjacent to the blast cleaning abrasives. The type, quantity, and placement of protection must be submitted for Engineer's approval, before cleaning and painting operations commence. The contractor shall have sufficient reserved quantity of protective devices, and shall be prepared to install same, allowing for unexpected variations in wind and other contingencies. Cleaning and surface preparation shall not proceed unless the required protective devices are in place.

Bridge Repair Method

No.1-12	Repainting

(2) Painting

The painting will be in accordance with Standard Specifications in Lao PDR.

(3) Quality Control

The Contractor is required to conduct and document quality control inspection of the cleaning and painting operations including, at a minimum, measurements of ambient conditions, surface profile, surface cleanliness, coating material acceptability, dry film thicknesses, and visual inspection for coating defects. The data shall be recorded in a Contractor's log maintained at the painting site.

The measurement of dry film thickness shall be measured by as following manner.

(a) Frequency: After every application of succeeding paint type.

(b) Procedure:

- Determine painted surface area.
- One (1) lot should be not more than 500m^2.
- Pick at least 25 random points representing the lot.
- Thickness of paint at each and every point should be taken 5 times.

Thickness of paint should be tested.

6. Measurement and Payment

6.1 Method of Measurement

The method of measurement as basis for payment shall be in total square meters of steel surface area, as identified by the Engineer.

6.2 Basis of Payment

Repainting works shall be paid for at a unit price per square meter, complete in place, which include all materials, containers, equipment, tools, labor, service advisor and work incidental for the repainting of the structure. Any indirect cost item shall not be paid separately. If scaffoldings and protective devices are provided, corresponding costs shall be deemed included in the square meter unit price.

Bridge Repair Method

No.1-13	Foot Protection

1. Description of Repair Method

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. Bridge scour is one of the main causes of bridge failure, because of river flooding. If this type of damage is not repaired, it could cause catastrophic failure to the bridge.

Figure AP 1.13.1 Typical Bridge Scour

Figure AP 1.13.2 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 (Figure AP 1.13.4). 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 (Figure AP 1.13.3).

Figure AP 1.13.4 Placing Rip Rap

Figure AP 1.13.3 Placing Sand Bags

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 Figure AP 1.13.5. However, by the selection of remedial measure, detailed investigation should be executed.

Bridge Repair Method

No.1-13	Foot Protection

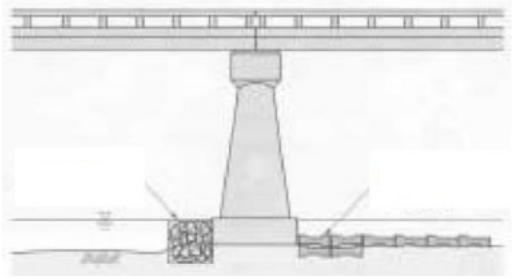
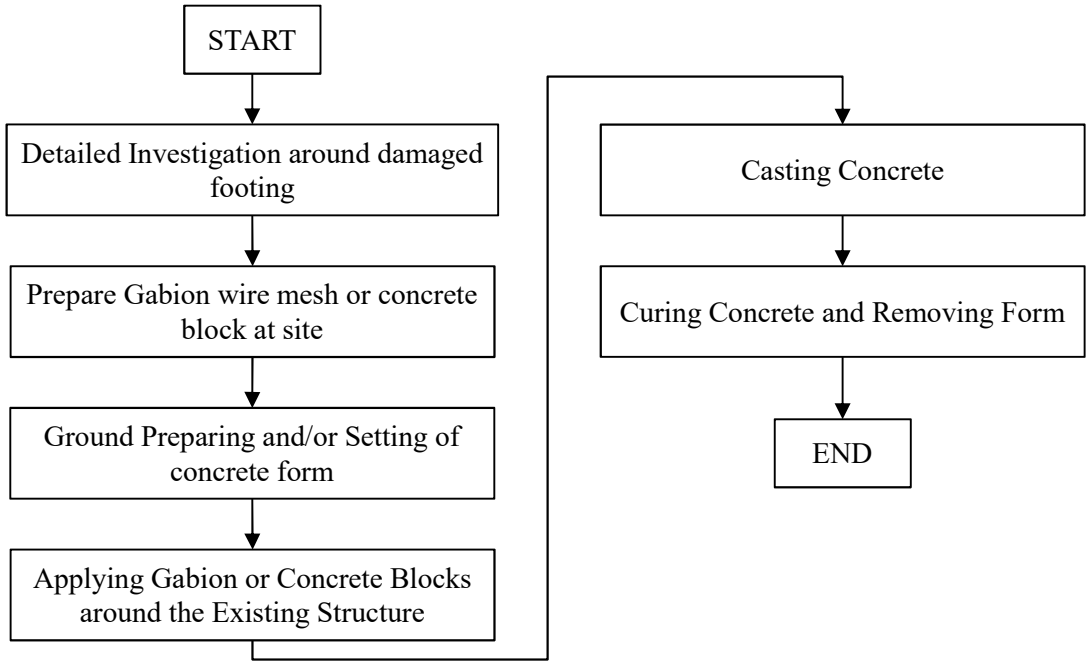


Figure AP 1.13.5 Foundation on Pile for Slope Protection Work

3. Work Sequence



4. Required Materials and Tools/Equipment

4.1 Required Material

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

4.2 Required Tools/Equipment

- Wire cutter
- Pliers and hand tools for binding of steel wires

Bridge Repair Method

No.1-13	Foot Protection

- Cleaning equipment comprising hand tools, shovel, and any other tools
- Truck crane
- Concrete mixer and form installation tool

5. Specification

5.1 Construction Requirement

(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 and/or concrete blocks. Carefully cut and remove the damaged/unacceptable portions of the gabion wires. While removing the damaged wires, care shall be exercised not to disturb the existing portion of the gabion work which is in intact condition.

(3) Filling missing material

Any missing infill material (stones/bricks/concrete blocks) 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. Then form work will be removed. Upon completion of works, remove all material, tools, and equipment from the site.

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.

Bridge Repair Method

No.1-14	Filling Pile Mortar/Concrete

1. Description of Repair Method

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.

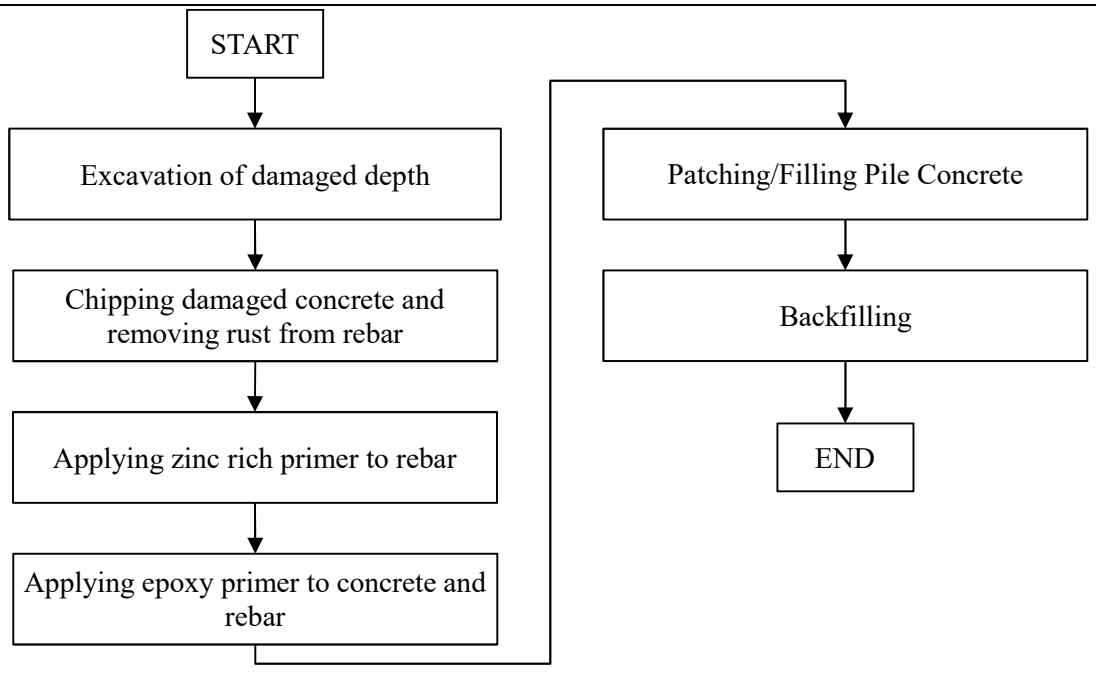
Patching repair of bored concrete pile is performed to restore small areas where sound concrete is damaged by spalling, scaling and impact. This method of repair is generally applied using trowel and require none or minimum formworks. On the other hand, Filling pile concrete is performed to restore missing concrete section of the bored pile where concrete of the section missed due to wrong measurement of the pile top elevation.

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



4. Required Materials and Tools/Equipment

Bridge Repair Method

No.1-14	Filling Pile Mortar/Concrete

4.1 Required Material

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

4.2 Required Tools/Equipment

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

5. Specification

5.1 Material Specifications

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

(1) Polymer Cement

Polymer cement mortar shall conform to the specifications shown in Table AP 1.14.1 or equivalent ASTM Specifications.

Table AP 1.14.1 Specifications of Polymer Cement

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

Bridge Repair Method

No.1-14	Filling Pile Mortar/Concrete

(2) Corrosion Protective Coating

The Protective Coating of rebar shall conform to the requirements of the specifications in Table AP 1.14.2.

Table AP 1.14.2 Specifications of Corrosion Protective Coating to Rebar

Property	Test Method	Unit	Specification
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 AP 1.14.3.

Table AP 1.14.3 Specifications of Zinc Rich Primer for Rebar

Property	Test Method	Unit	Specification
Thermal Expansion	ASTM C531	mm/mm^oC	2.0×10^{-5}
Gloss at 60° Angle	ASTM D523	-	Flat
Adhesion	ASTM D3359	-	Minimum 3A
Salt Spray Resistance	ASTM D3-37	-	Excellent
%Zinc by Weight in Dried Film Test	-	%	87.5 ± 2

Bridge Repair Method

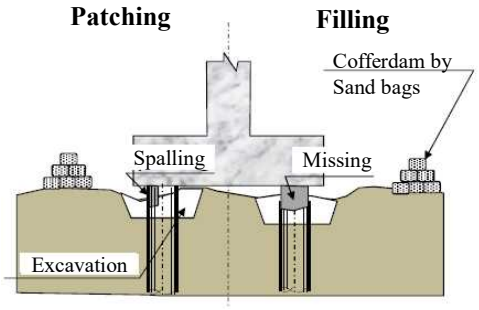
No.1-14	Filling Pile Mortar/Concrete

5.2 Construction Requirement

(1) Excavation

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

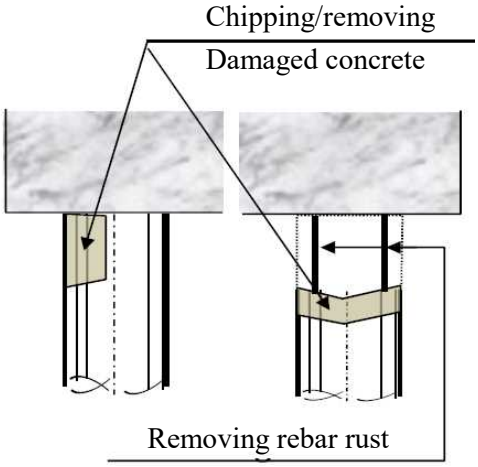
Temporary cofferdam by such as sand bags and a submersible pump shall be considered, if necessary. With consideration of safety, in case, excavation depth is required deeper than 1.0m, a new pile shall be constructed just nearby the damage pile.



(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.

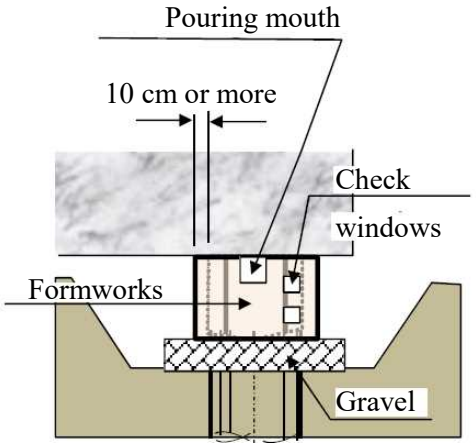
(4) Applying Epoxy Primer

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 bigger than the pile radius. However, it is considerable to use surrounding soil wall instead of formwork. Formworks shall consider 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

1) Applying Polymer Mortar

The mortar should be placed in layers of about 20 mm thickness. Compact each layer thoroughly over

Bridge Repair Method

No.1-14	Filling Pile Mortar/Concrete

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.

2) Pouring Concrete

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

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

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

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.

(7) Curing

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

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

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

Bridge Repair Method

No.1-14	Filling Pile Mortar/Concrete

(8) 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

(1) Patching of pile concrete

The Engineer will measure the area prepared for Patching pile 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.

(2) 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 Filling 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.

Bridge Repair Method

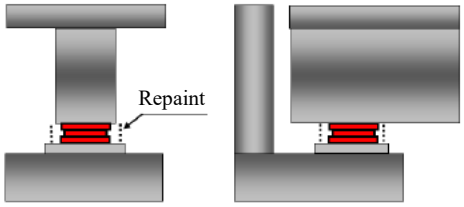
No.1-15	Partial Repair of Bearings

1. Description of Repair Method

Steel bearings are provided at bridge abutments and piers. Typically, due to the deterioration of water proofing at expansion joints over the years, steel bearings underneath the superstructure are subjected to corrosion.

Bearings serve as interface between girder and substructure. The gap between girder's bottom surface and top level of bearing seat is usually narrow, making it difficult to perform repainting of bearings. Nevertheless, it is necessary to ensure that condition is dry and satisfactory before carrying out any surface preparation. Repainting of bearings shall proceed after surface preparation, in accordance with Appendix.1 No.12 Repainting of this manual. If 1st grade surface preparation is required, epoxy zinc rich primer and polyurethane aluminum paint shall be applied. Meanwhile, epoxy polymide primer and polyurethane aluminum paint shall be applied for 2nd grade surface preparation. Finally, if 3rd grade surface preparation is necessary, special anti-corrosion paint shall be provided.

Repaint of Steel Bearing



2. Application Criteria

Steel bearings shall be subject to repainting if based on results of bridge inspection, a "bad" rating is given due to observed severe corrosion or section loss of more than 20%.

3. Work Sequence

(1) Scaffoldings

Repainting of bearings on abutments will not require scaffolding. On piers however, scaffoldings need to be installed to access the bearings, and for safety purposes.

(2) Surface Preparation of Steel Bearings

Surface preparation for steel bearings is requisite to repainting required.

The 1st Grade preparation is intended for severely corroded steel surface, where sand blast machine is utilized to achieve near white blast surface.

The 2nd Grade preparation is for fairly to badly corroded steel surface where electric disc grinder will be necessary to remove the remaining coating film.

Lastly, 3rd Grade preparation is applied to surfaces where sound coating film still remains. Cleaning is for this preparation requires wire brush, scraper and electric disc grinder.

During removal of coating film, it is important to ensure that the works do not have impacts to the environment as it could scatter dust, dirt and scale that may contain lead and other harmful elements.

(3) Painting

Painting is mainly applied with the use of paint brush and paint roller. These tools are environment

Bridge Repair Method

No.1-15	Partial Repair of Bearings

friendly and save costs. Quality control of painting should be strictly executed to maintain required coating film thickness. Measurement of coating film thickness after it dries can be easily done using thickness meter gauge.

4. Required Materials and Tools/Equipment

4.1 Required Material

- Zinc-rich base primer
- Polyurethane Aluminum Paint – Aluminum paint shall consist of aluminum bronze powder or paste of the required fineness and composition to which shall be added the specified amount of agent component.
- Thinner
- Modified epoxy polyamide primer
- Special Anti-Corrosion paint

4.2 Required Tools/Equipment

- Water jet spray, water tank, water hose, brush and generator for washing bearing.
- Wire brush, scraper, electric disc grinder, sand blast machine, air compressor and generator for surface preparation
- Paint brush and paint roller

Bridge Repair Method

No.1-15	Partial Repair of Bearings

5. Specification

5.1 Material Specifications

Repainting shall be applied according to three grades of surface preparation as in Table AP 1.15.1, Table AP 1.15.2, and Table AP 1.15.3. The materials shall be approved by the Engineer through mill certificate of the supplier. Appropriate material should be selected in accordance with manufacturer's instructions.

Table AP 1.15.1 Specifications for 1st Grade Surface Preparation

Function	Description	DFT(μ)	Test Method	Painting Interval (hours)
Surface Preparation	Near white Blast Cleaning should be done to remove paint, rust, scale, dirt, grease or other foreign matters. Solvent cleaning by lacquer thinner to remove dirt, oil, grease and other contaminants. All surfaces to be painted must be dry and free from dust. (SSPC-SP10)			4
1st Coat: Primer	Epoxy Zinc Rich Primer (SSPC-Paint No.20)	75	ASTM D520	8
2nd Coat: Top Coat (for lower flange plate)	Epoxy Zinc Rich Primer (SSPC-Paint No.20)	75	ASTM D520	8
3rd Coat: Intermediate Coat	Polyurethane Aluminum Paint (SSPC-Paint No.36)	50	ASTM D16, Type V Polyurethane	4
4th Coat: Top Coat	Polyurethane Aluminum Paint (SSPC-Paint No.36)	50	ASTM D16, Type V Polyurethane	4

Table AP 1.15.2 Specifications for 2nd Grade Surface Preparation

Function	Description	DFT(μ)	Test Method	Painting Interval (hours)
Surface Preparation	Power Tool Cleaning to remove existing paint, rust, scale, stains and other foreign matters. Solvent cleaning by lacquer thinner to remove dirt, oil, grease and other contaminants. All surfaces to be painted must be dry and free from dust. (SSPC-SP10)			4
1st Coat: Primer	Modified Epoxy Polyimide Paint (SSPC-PS13.01)	75	ASTM D1652	8
2nd Coat: Top Coat (for lower flange plate)	Modified Epoxy Polyimide Paint (SSPC-PS13.01)	75	ASTM D16521	8
3rd Coat: Intermediate Coat	Polyurethane Aluminum Paint (SSPC-Paint No.36)	50	ASTM D16, Type V Polyurethane	4
4th Coat: Top Coat	Polyurethane Aluminum Paint (SSPC-Paint No.36)	50	ASTM D16, Type V Polyurethane	4

Bridge Repair Method

No.1-15	Partial Repair of Bearings

Table AP 1.15.3 Specification for 3rd Grade Surface Preparation

Function	Description	DFT(μ)	Test Method	Painting Interval (hours)
Surface Preparation	Hand tool and power tool cleaning device to remove existing paint, rust , scale, stains and other foreign matters Solvent cleaning with lacquer thinner required to remove dirt, oil, grease and other contaminants All surfaces to be painted must be dry and free from dust			4
1st Coat	Special anti-corrosion paint	250	JIS A6909 / ASTM D7234	2
2nd Coat: Top Coat	Special anti-corrosion paint	250	JIS A6909 / ASTM D7234	2

5.2 Construction Requirement

(1) Surface Preparation

The Contractor shall clean up the site and assess the defects due to corrosion on bearings. The Contractor shall then submit a plan drawing related to proposed painting to the bearings, subject to approval of the Engineer. The Contractor, in close coordination with the Engineer, shall also propose the suitable grade of surface preparation and painting system.

(2) Painting

Painting for bearing shall be done using hand paint brush. After surface preparation, the primer or 1st layer coating shall be painted immediately, within 4 hours. Intermediate layer and top coat paint shall be applied as well using hand paint brush. After paint coating has dried, total thickness of coating film shall be measured using an electric thickness gauge.

6. Measurement and Payment

6.1 Method of Measurement

The method of measurement for repainting of bearings shall be by the total square meters of steel surfaces area, determined with the Engineer.

6.2 Basis of Payment

Repainting works will be paid for at a unit price per square meter as item for “Partial Repair of Bearings”, complete in place, which shall include all materials, containers, equipment, tools, labor, service advisor and work incidentals for the works. Any indirect cost item shall not be paid separately. This shall be deemed included in the square meter price.

Bridge Repair Method

No.1-16	Replacement of Bearing

1. Description of Repair Method

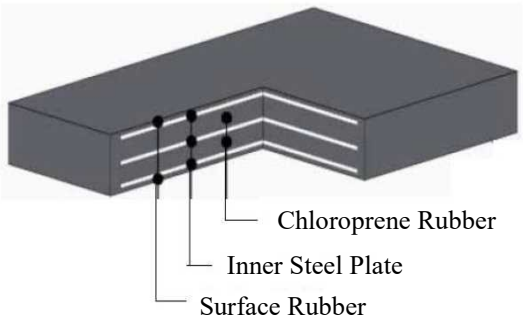
Effective service life of elastomeric bearings is estimated to be 15 – 25 years. As the material ages during its serviceability period, it exhibits severe bulging or cracking. These are signs that the elastomeric bearings need to be replaced.

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

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

Sample of Replacement Bearing

Rubber Bearing



2. Application Criteria

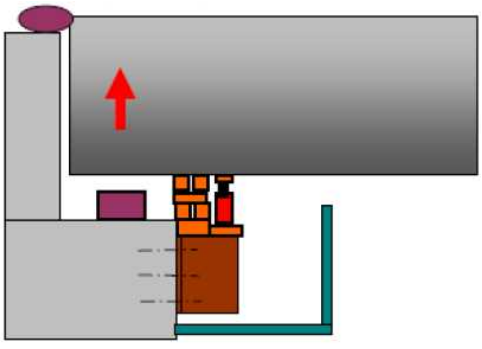
Replacement of bearing shall be implemented if existing rubber bearings already exhibited severe cracks and abnormal bulging. Old steel bearings need to be replaced especially if loose connections were observed. This repair method form part of the jack-up girder method described in Section 9-3.

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

3. Work Sequence

3.1 Jack-up Girder

Jack-up girder process shall be referred to No.17 Jack-up girder of Appendix.1. The surface of expansion joint shall be secured to provide safety for passing traffic during jacking up process. Moreover, the height difference between surface of abutment and girder shall be kept below 10 mm.

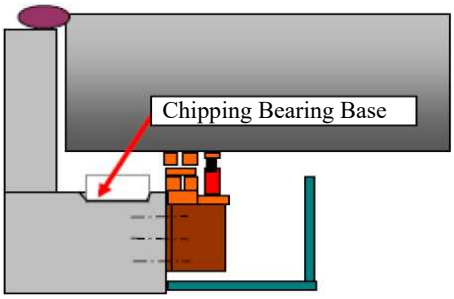


Bridge Repair Method

No.1-16	Replacement of Bearing

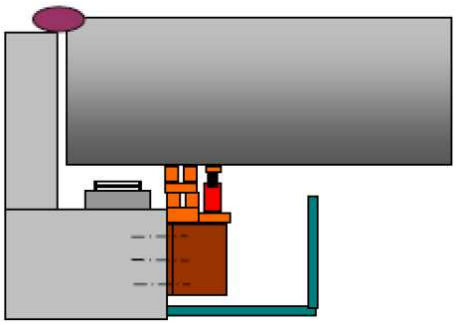
3.2 Dismantle existing Bearing and chipping bearing base

After jacking-up process, chip-off concrete bearing base to remove existing bearings.



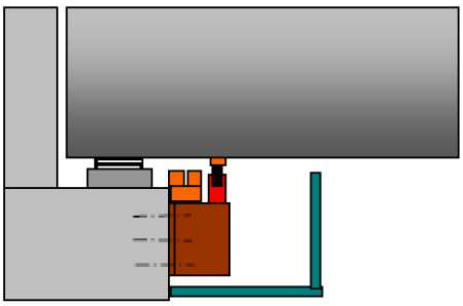
3.3 Cast New Bearing Seat and Set up New Bearings

After concrete chipping and new required bed support replacement with rebar will be installed using non-shrink grout, the new bearings shall be set up at appropriate position and level. The level shall consider additional factor such as compressive displacement of elastic rubber bearing.



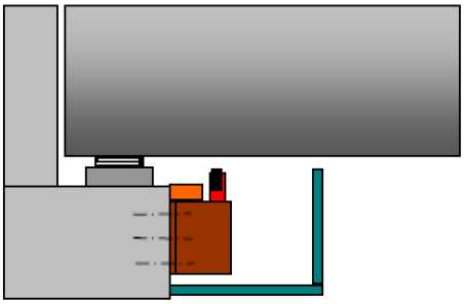
3.4 Jack Down Girder after Curing

After curing of bearing be, it should be inspected to check the level and stability before the girder is jacked down and consequently supported by the new rubber bearing. Final position and height of the new bearing shall be verified, subject to approval of the Engineer.



3.5 Dismantle Jacks and Temporary Supports for the Final Work

After replacement of the new rubber bearings are accomplished, jack device and temporary supports shall be dismantled. Steel surfaces shall be painted, if found necessary.



4. Required Materials and Tools/Equipment

4.1 Required Material

- Elastomeric bearing pads.
- Rebar
- Mortal/concrete

Bridge Repair Method

No.1-16	Replacement of Bearing

4.2 Required Tools/Equipment

- Hydraulic Jack
- Electrical Jackhammer
- Trowel

5. Specification

5.1 Material Specifications

1) Bearing Pads

Elastomeric bearing pads shall confirm to AASHTO M251.

Property	Test Method	Unit	Specification
Hardness, Durometer A	ASTM D2240	-	60±5

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

2) Other Materials

- For bearing base mortar, refer to mortar described in Apprndix.1 No.5 Recasting concrete.

5.2 Construction Requirement

(1) Jack-up Girder

The Contractor shall submit the shop drawings together with the load calculations for jack capacity of jack up girder shall be approved by the Engineer, considering dead load and live load during the replacement work.

(2) Casting New Bearing Seat and Set up New Bearings

The Contractor shall submit shop drawings stating the materials to be used and specifications for the new bearing seat to be approved by the Engineer, prior to execution of related works. After providing temporary support for the girders near the bearing locations, old bearings shall be removed. Position and level for the new bearings shall be set-up in accordance with approved plans and specifications.

(3) Jack-down Girder after Curing

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

(4) Dismantle Jacks and Temporary Supports as Final Work

When the reaction is safely transferred from the jack to the new bearing, jacking device shall be dismantled. Temporary support materials as well shall also be dismantled safely.

Bridge Repair Method

No.1-16	Replacement of Bearing

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.

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.

Bridge Repair Method

No.1-17	Jack-Up Girder

1. Description of Repair Method

Jack up girder method is applied for replacement of bearings and re-arrangement of existing bearing. The computation of jack-up reaction shall be the responsibility of the designated Structural Engineer. Once the required quantity and capacity of hydraulic jacks are determined, this repair method shall then progress. Required scaffoldings shall also be provided. Jack-up device and temporary supports and jack base bracket shall be fabricated and installed below the concrete or steel girder near bearing locations. For steel girders, jack stiffener shall be welded in proper position before proceeding with raising the girder. During jacking operations, traffic may remain open but with under restricted speed and flow to maintain safety. The operation shall be simultaneously performed for all the girders. The height to be raised on a cyclic motion shall be limited to less than 5 mm in order to ensure constant reactions are transmitted from all the girders. The jack up procedure shall be repeated until the existing bearings are accessible for dismantling. The ideal jack up height could reach between 10 mm to 20 mm.

Sample of Replacement Bearing by Jack-up Girder

Hydraulic jack

50-ton hydraulic jack

Bridge Repair Method

No.1-17	Jack-Up Girder

2. Application Criteria

In case loose connection of steel bearings or bulging/cracking of rubber bearings are judged to as "Bad" as per suggested Condition Rating Criteria, jack-up method will be initiated to perform necessary repairs or replacement of bearings.

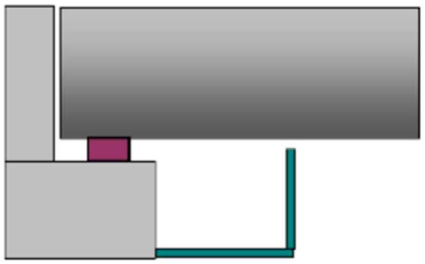
In case abnormal displacement of steel and rubber bearing are judged as "Bad", the jack-up method is also utilized for lifting the girder to reposition the bearing locations.

3. Work Sequence

3.1 For Concrete Girder

(1) Preparation of materials, equipment and site cleaning

The Scaffolding is installed to prepare jack-up method to proceed. The jack base bracket shall be fabricated in the factory which is approved by the Engineer.



(2) Installation of Jack base frame

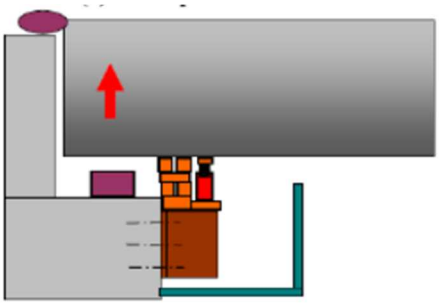
The Jack-base bracket is installed using epoxy anchor through drilled holes for anchor bolts.

Hydraulic jack with capacity furnished by designated structural engineer is set up on the jack-base bracket. Temporary supporting member shall also be provided.

(3) Jacking up

Jack-up operations shall be simultaneously carried out for all the girders. For this condition, jacking up height is limited to 5 mm for each jack-up motion.

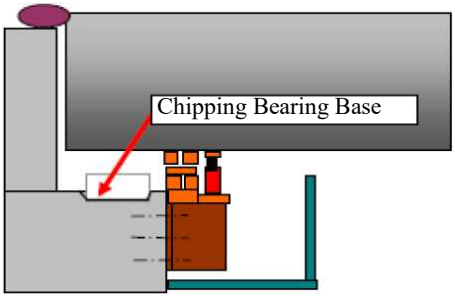
The method is repeated in gradually until enough jacking up height is achieved to allow for dismantling of the existing bearing.



(4) Chipping bearing base and remove existing Bearing

Concrete bearing base is chipped off to dismantle the existing bearings.

A slope between bridge approach and the expansion joint shall be maintained for passing traffic during jacking-up operations.



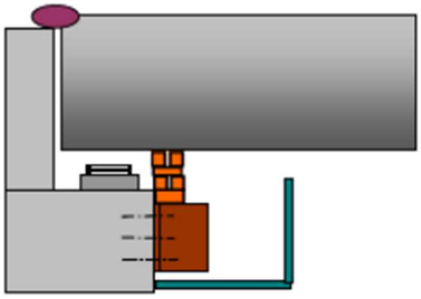
Bridge Repair Method

No.1-17	Jack-Up Girder

(5) Making new bearing base

Additional re-bars for the new bearing base shall be arranged.

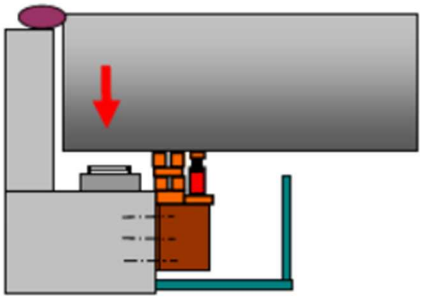
After concrete is completely placed, new rubber bearings are installed on the bearing base. During this operation, the girder shall be temporarily supported. The measurement of height, location shall be carefully verified by a designated inspector.



(6) Jack down

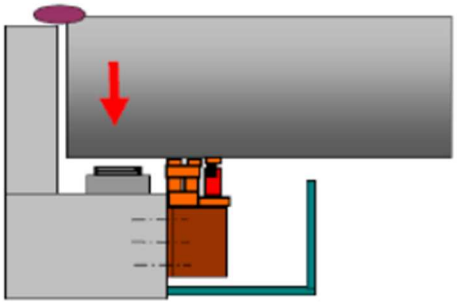
1) Jack down process, dismantle support in cyclic process

If the new bearing installed is determined satisfactory, jack down operations shall commence. It is important to maintain safety during this operation. Jacking down shall be carried out gradually while carefully removing the temporary supporting members.



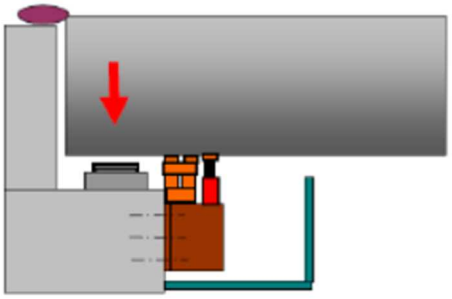
2) Jack down

If the temporary support touches the lower surface of the girder during jack down operations, the jack base plate shall be changed with a lesser thickness. Stroke shall be extended to jack down. These steps shall be repeated in cycle. For safety purposes, each stroke should maintain a height of less than 5 mm.



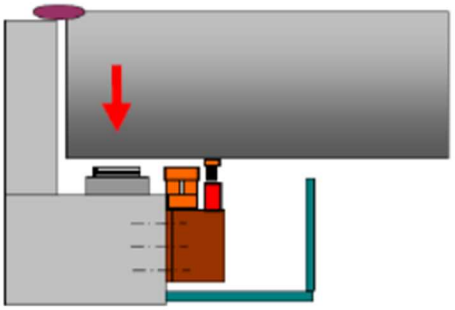
3) Dismantle jack

If the temporary support keeps touching the concrete surface, dismantle jack and remove jack base plate gradually.



4) Dismantle Support

The temporary support shall be taken off from the concrete surface by jacking up slightly. The temporary support shall be dismantled gradually for every 5 mm jack down movement.

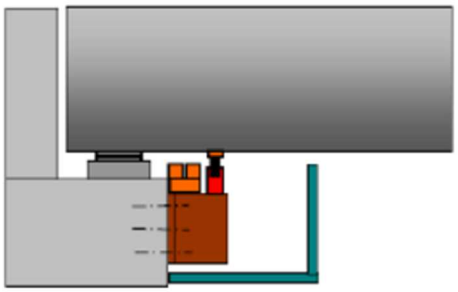


Bridge Repair Method

No.1-17	Jack-Up Girder

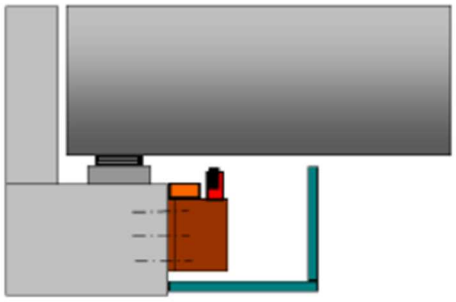
5) Jack down

Once the concrete girder finally rests completely on the bearings during jacking down motion, the exact location between the girder and bearing shall be measured immediately. If dimensions are acceptable, the jack can be dismantled completely.



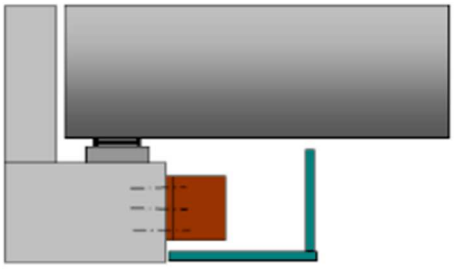
(7) Verification of measurement

Verification measurement shall be conducted to ensure final height, and exact location of all bearing positions. If not satisfactory, re-jack operations shall be repeated to perform adjustments.



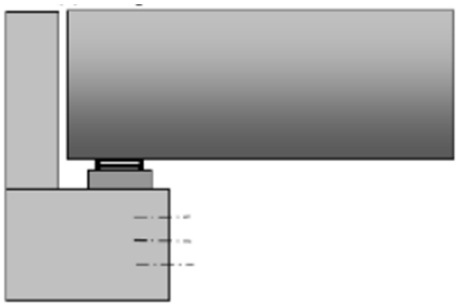
(8) Dismantle Jacks and temporary supports

Jacks and temporary support materials shall be dismantled.



(9) Completion

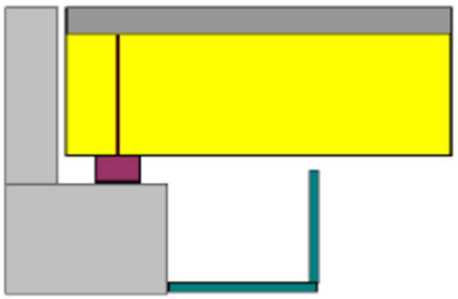
Clean-up site and ensure the measurements are approved by the Engineer.



3.2 For Concrete Girder

(1) Preparation of materials, equipment and site cleaning

The Scaffolding is installed to prepare jack-up method to proceed. The jack base bracket shall be fabricated in the factory which is approved by the Engineer.

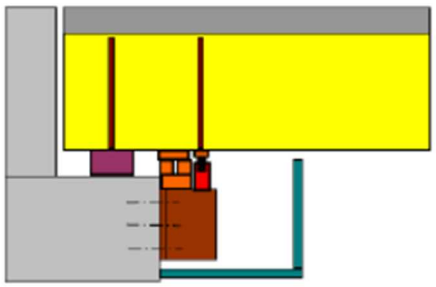


Bridge Repair Method

No.1-17	Jack-Up Girder

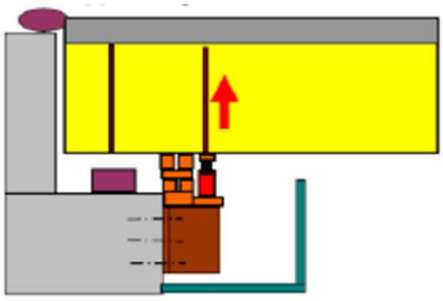
(2) Welding temporary jack stiffeners

Jack stiffeners shall be welded to both sides of web plate. Jack-base bracket is installed using epoxy anchor installed at drilled holes for anchor bolts.



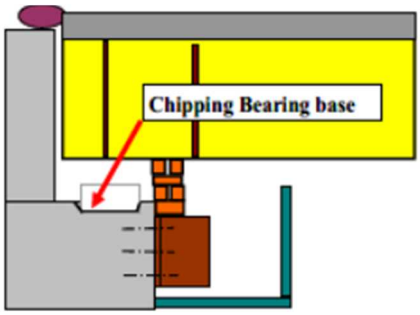
(3) Jacking up

Jack-up operations shall be simultaneously carried out for all the girders. For this condition, jacking up height is limited to 5 mm for each jack-up motion. The method is repeated in gradually until enough jacking up height is achieved to allow for dismantling of the existing bearing.



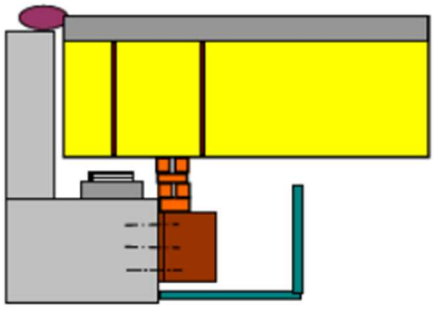
(4) Chip-off bearing base and remove existing bearing

Concrete bearing base is chipped off to dismantle the existing bearings. A slope between bridge approach and the expansion joint shall be maintained for passing traffic during jacking-up operations.



(5) Making new Bearing base

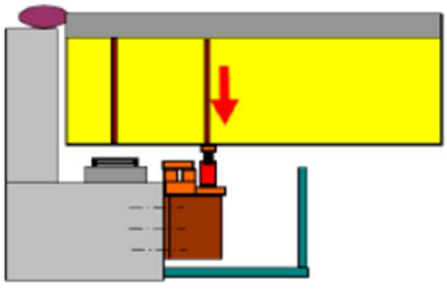
Additional re-bars for the new bearing base shall be arranged. After concrete is completely placed, new rubber bearings are installed on the bearing base. During this operation, the girder shall be temporarily supported. The measurement of height, location shall be carefully verified by a designated inspector.



(6) Jack down

1) Jack down process, dismantle support in cyclic process

If the new bearing installed is determined satisfactorily, jack down operations shall commence. It is important to maintain safety during this operation. Jacking down shall be carried out gradually while carefully removing the temporary supporting members.

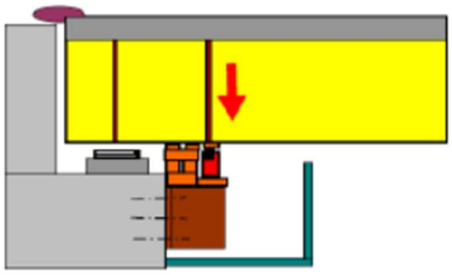


Bridge Repair Method

No.1-17	Jack-Up Girder

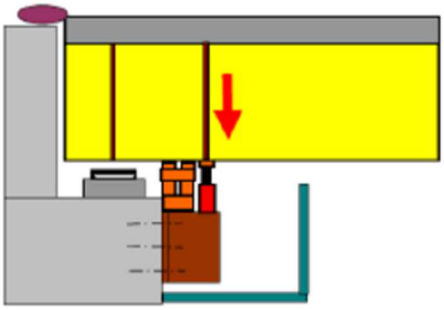
2) Jack down

If the temporary support touches the lower surface of the bottom flange during jack down operations, the jack base plate shall be changed with a lesser thickness. Stroke shall be extended to jack down. These steps shall be repeated in cycle. For safety purposes, each stroke should maintain a height of less than 5 mm.



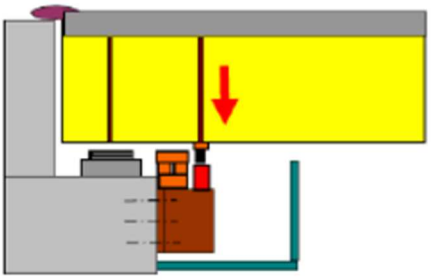
3) Dismantle jack

If the temporary support keeps touching the lower flange, dismantle jack and remove jack base plate gradually.



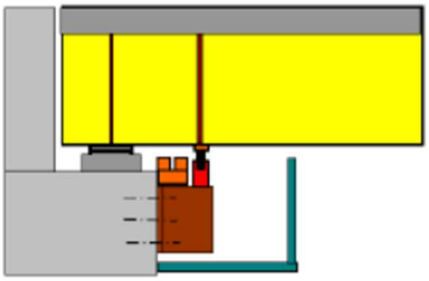
4) Dismantle support

The temporary support shall be taken off from the steel girder by jacking up slightly. The temporary support shall be dismantled gradually for every 5 mm jack down movement.



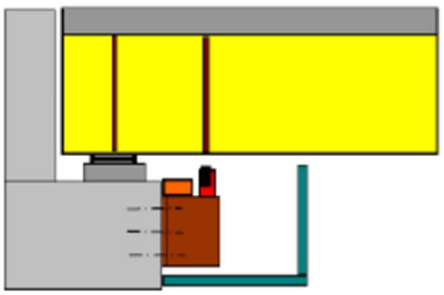
5) Jack down

Once the lower flange finally rests completely on the bearings during jacking down motion, the exact location between the girder and bearing shall be measured immediately. If dimensions are acceptable, the jack can be dismantled completely.



(7) Inspection of measurement

Verification measurement shall be conducted to ensure final height, and exact location of all bearing positions. If not satisfactory, re-jack operations shall be repeated to perform adjustments.

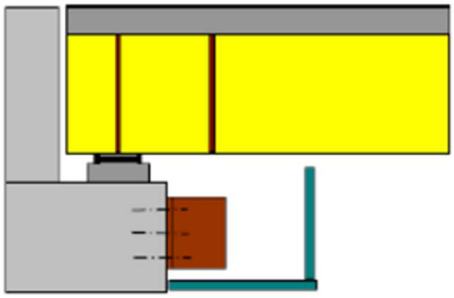


Bridge Repair Method

No.1-17	Jack-Up Girder

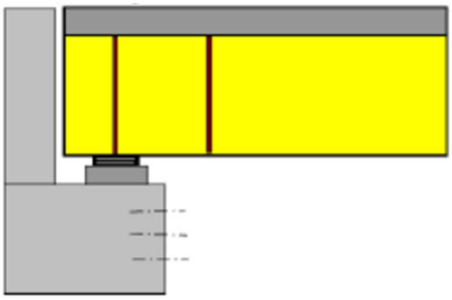
(8) Dismantle Jacks and temporary supports

Jacks, temporary support materials shall be dismantled. Paint steel portion, if found necessary. Dismantle any installed scaffoldings.



(9) Completion

Cleanup site and ensure the measurements are approved by the Engineer.



4. Required Materials and Tools/Equipment

4.1 Required Materials

- New bearings, (if the purpose is Replacement of Bearing)
- Epoxy anchor bolt for jack base bracket
- Temporary support material for jacking up motion
- Paint (if required)

4.2 Required Tools/Equipment

- Hydraulic Jack
- Welding machine
- Hammer
- Electric jackhammer for chipping
- Concrete drilling machine

5. Specification

5.1 Construction Requirement

(1) Preparation of materials, equipment and site cleaning

The contractor shall submit for Engineer's approval, shop drawing for the work required. Jacking capacity, epoxy anchor size its required quantities shall be as per Engineer's advice.

Bridge Repair Method

No.1-17	Jack-Up Girder

(2) Installation of Jack base frame

Epoxy anchor bolt hole shall be installed on the vertical face of pier/abutment using electric drill device. Epoxy adhesive shall be filled inside the holes and anchor bolts set up then cured in proper time. If curing period of epoxy anchor is completed, the jack base frame shall be installed. The Contractor shall submit tensile test of epoxy anchor for Engineer's approval.

(3) Jacking up

The Contractor shall submit jack devices guarantee certificate of performance and service data for approval of the Engineer. The jack accessories shall be verified and confirmed by its supplier prior to installation for the girder, to ensure no oil leaks. The limit of relative height difference below 5mm during jacking up motion shall be maintained for quality control.

(4) Chipping bearing base and dismantle existing bearing

After jack up is completed, existing bearings shall be dismantled/re-positioned. If bearings need to be replaced, chipping off of concrete shall be initiated. Girders shall be supported with temporary support member until the jack down operations.

(5) Making new Bearing base

Chipping off bearing base shall be initiated using electric jack hammer. Additional rebars for the new bearing base shall be placed. The contractor shall submit measurement verifications of actual rebar arrangement for Engineer's approval. If arrangement is satisfactory, concrete shall be poured to the new bearing base. Concrete shall then be allowed to cure properly. The Contractor shall submit test results of concrete compressive strength to the Engineer for his approval. The new rubber bearings shall be installed at proper locations on the bearing base.

(6) Jacking down

After approval of inspection, the contractor shall jack down the girder carefully. It should be noted that jack down motion is dangerous than jack up motion. The Contractor should therefore strictly maintain the gradual jack down motion to 5mm for safety purposes.

(7) Verification Measurement

During jack down motion, the reaction shall be consequently transferred to the new bearing from the temporary support member. The Contractor shall submit the result of verification measurement for Engineer's approval.

(8) Dismantle jack and temporary support

The jack, temporary support and scaffoldings shall be dismantled immediately.

(9) Completion

Clean-up site and ensure that final measurements are acceptable and approved by the Engineer.

Bridge Repair Method

No.1-17	Jack-Up Girder

6. Measurement and Payment

6.1 Method of Measurement

The quantity for this work item shall be the actual quantity placed and accepted during the progress of the work. The temporary support material shall be included in quantity.

6.2 Basis of Payment

The accepted quantities, measured as prescribed in 6.1 shall be paid for at a contract unit price for each of the approved pay item included in the bill of quantities.

Bridge Repair Method

No.1-18	Replacement of Expansion Joint (Installing Asphalt Plug Joint)

1. Description of Repair Method

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

The usual gap between concrete edges is around 20 mm considering temperature in the Lao PDR as 25°C ± 10°C. The movement of a 20 m bridge span due to changes in temperature is 12 × 10-6 / °C × 20 m × (± 10°C) = ± 2.4mm and the movement of the same span due to traffic load is approximately less than 5 mm. Total movement of a 20 m span RCDG bridge is below ± 10 mm. With these considerations, the most suitable repair measure for damaged asphalt sealant is the installation of asphaltic plug joint.

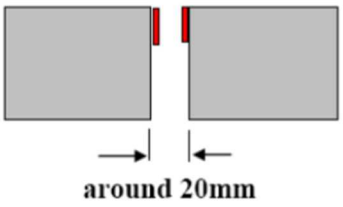


Figure AP 1.18.1 Sealant Asphalt Joint

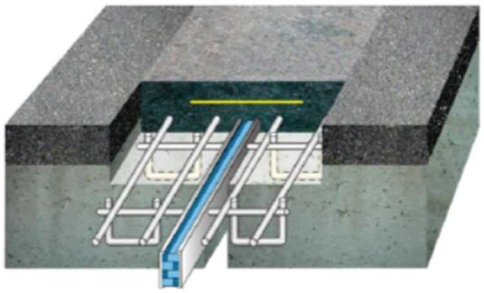


Figure AP 1.18.2 Type of Asphaltic Plug Joint

Cleaning of the gap

Flexible Asphalt pouring

2. Application Criteria

Asphaltic plug joints are mainly applied on RCDG bridges and steel girder bridges on fixed bearings. This repair method shall be implemented if the following conditions are rated as “Bad” as per suggested condition rating criteria:

- Water leakage: detected area > 50%

Bridge Repair Method

No.1-18	Replacement of Expansion Joint (Installing Asphalt Plug Joint)

- Abnormal space/noise: detected
- Difference in Elevation: 30 mm at expansion gap
- Deteriorated Sealant: Pourable joint sealant almost completely lost

3. Work Sequence

3.1 Dismantle Existing Damaged Asphalt Joint Sealant

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

3.2 Chipping surface concrete

Chip-off edges of concrete to install steel frame and to insert the form to narrow gap. (Proper gap for seamless joint is less than 25 mm.)

3.3 Install steel frame

Steel frame shall be fabricated with box frame and rebar. This frame shall be fixed by welding between concrete anchor and rebar.

3.4 Rebar Anchor

Besides intersection of rebar, the concrete anchor shall be inserted for every intersection of rebar.

3.5 Pouring Flexible Asphalt

Flexible Asphalt shall be poured to the chipped off edges. The height of pouring is half of total thickness.

Bridge Repair Method

No.1-18	Replacement of Expansion Joint (Installing Asphalt Plug Joint)

3.6 Installation of Expansion Sheet

Expansion Sheet shall be spread on the first layer of flexible asphalt.

3.7 Pouring Flexible Asphalt

Flexible asphalt (asphalt- rubber chips) shall be poured as second layer. The surface of flexible asphalt shall not be compact or tamping until decrease the temperature.

4. Required Materials and Tools/Equipment

4.1 Required Material

- Steel frame (welded with anchor rebar)
- Concrete anchor with steel bar
- Expansion sheet
- Flexible Asphalt

4.2 Required Tools/Equipment

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

Bridge Repair Method

No.1-18	Replacement of Expansion Joint (Installing Asphalt Plug Joint)

5. Specification

5.1 Material Specifications

Pre-fabricated steel frame : ASTM A36 or equivalent,

Flexible asphalt shall be based in accordance with Table 8-1. The material shall be approved by the Engineer through mill certificate of the supplier.

Table AP 1.18.1 Specification of Asphalt Compound

Property	Test Method	Unit	Specification
Density	ASTM D1188	g/cm3	2.26±0.05
Splitting Strength	ASTM D4123-82	N/mm2	1.57±0.29
Deformation (Flow value)	JIS K2207 / ASTM D1559	1/100cm	140±20

5.2 Construction Requirement

(1) Chipping surface concrete

The surface of concrete at the location of the existing damaged joint shall be chipped off for purposes of installing new steel frame. After chipping, the contractor shall verify the sizes and spacing of existing reinforcements.

(2) Install Steel Frame

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

(3) Pouring Flexible Asphalt

Prior to pouring, the Contractor shall submit material test results for the flexible asphalt, for approval of the Engineer.

The flexible asphalt shall be subjected to strict quality control especially for the temperature control requirements. Using mini asphalt cooker, flexible asphalt shall be cooked with minimum temperature of 180℃ and not to exceed 288℃. The asphalt shall be poured on the gap until half of total thickness as first layer.

(4) Expansion Sheet

Expansion sheet shall be laid on first layer of flexible asphalt using gas burner.

(5) Pouring Flexible Asphalt

The 2ndlayer of flexible asphalt shall be subjected to strict quality control especially for the temperature control requirements.

Bridge Repair Method

No.1-18	Replacement of Expansion Joint (Installing Asphalt Plug 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 defined by the Engineer.

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.

Bridge Repair Method

No.1-19	Replacement of Small Joints

1. Description of Repair Method

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

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

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

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

Sample of Waterproof Type Expansion Joint

2. Application Criteria

The replacement of steel expansion joint shall be implemented if the following conditions are rated as “Bad” as per suggested condition rating criteria:

- Water Leakage: Detected area > 50%
- Abnormal space/noise: Detected
- Difference in elevation: Difference in elevation is >30mm at expansion gap
- Displacement: Pourable joint sealant maybe almost completely lost
- Cracking: Cracking on primary members especially in welded parts

Meanwhile, replacement of rubber expansion joint shall be implemented if the following condition criteria are rated “Bad”:

- Water leakage: detected area >50%

Bridge Repair Method

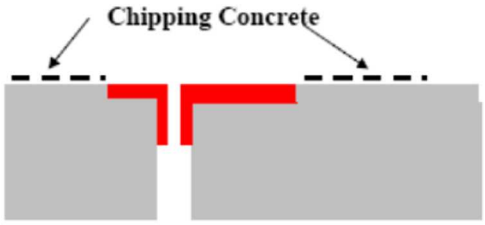
No.1-19	Replacement of Small Joints

- Abnormal Space/ Noise: Detected
- Difference in Elevation: >30mm at expansion gap
- Rupture: Rubber seal dislodged or peeled-off
- Abnormal Space/ Noise: Detected
- Deteriorated Sealant: Joint sealant maybe almost completely lost.

3. Work Sequence

3.1 Cut concrete surface

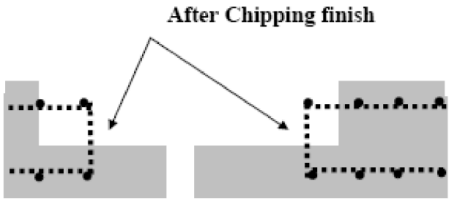
Using concrete sawing device, concrete surface shall be cut in transverse direction.



3.2 Chipping off concrete/ Dismantling defective expansion joint

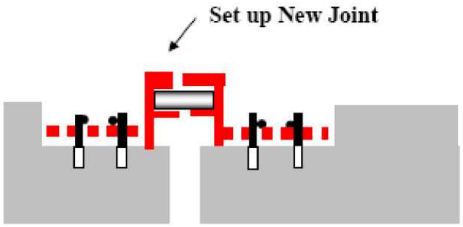
Concrete shall be continuously chipped off to achieve the required positioning for the new expansion joint. Exposed existing rebars shall remain to maintain the strength.

The damaged expansion joint shall then be dismantled after chipping off concrete.



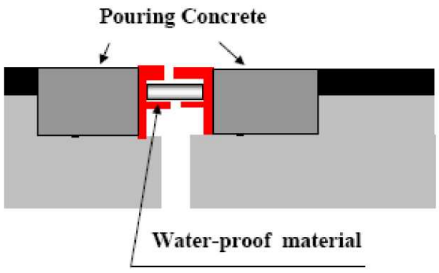
3.3 Set up new expansion joint

The new expansion joint with water-proof device shall be installed. Transverse rebar (16 mm dia.) shall be fixed with mechanical anchors.



3.4 Pouring Concrete

After verification measurements, concrete shall be poured, and then cured, to complete the works.



Bridge Repair Method

No.1-19	Replacement of Small Joints

4. Required Materials and Tools/Equipment

4.1 Required Material

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

4.2 Required Tools/Equipment

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

5. Specification

5.1 Material Specifications

For new expansion joint:

- Steel plates, anchor bars: ASTM A36 or equivalent
- Mortar/concrete: comply with the following specifications

Table AP 1.19.1 Specifications of Polymer Cement Patching Material

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

- Expansion joint rubber seal: comply with the following specifications:

Table AP 1.19.2 Specification of Asphalt Compound

Property	Test Method	Unit	Specification
Tensile Strength	JIS K6251/ASTM D412	MPa	≥0.98
Elongation at break	JIS K6251/ASTM D412	%	≥100

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.

Bridge Repair Method

No.1-19	Replacement of Small Joints

5.2 Construction Requirement

(1) Cut Concrete Surface

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

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

(2) Chip off Concrete and Dismantle Expansion Joint

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

(3) Set up new expansion joint

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

(4) Set up new expansion joint

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.

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.

Bridge Repair Method

No.1-20	Slope Protection with Foundation Supported by Piles

1. Description of Repair Method

Slope protection around the abutment is often damaged due to scouring, rapid river flow, or improper construction, as shown in Figure AP 1.20.1. In most of the defective cases observed, foundation for the slope protection was not provided; hence, the protection eventually fails due to either sliding or scouring. Repair method for the slope protection involves provision of appropriate foundation at its base.

Figure AP 1.20.1 Broken Slope Protection

2. Application Criteria

Appropriate type will be selected from among slope protection works such as stone masonry, grouted riprap and concrete masonry. The foundation should be a concrete base with wooden pile as shown in Figure AP 1.20.2. The wooden pile is normally driven to a minimum depth of 2.0 m. The foundation is usually placed at 1.0 m level below the river bed.

This criterion is only applicable as a standard repair method to damaged protection near small and medium rivers.

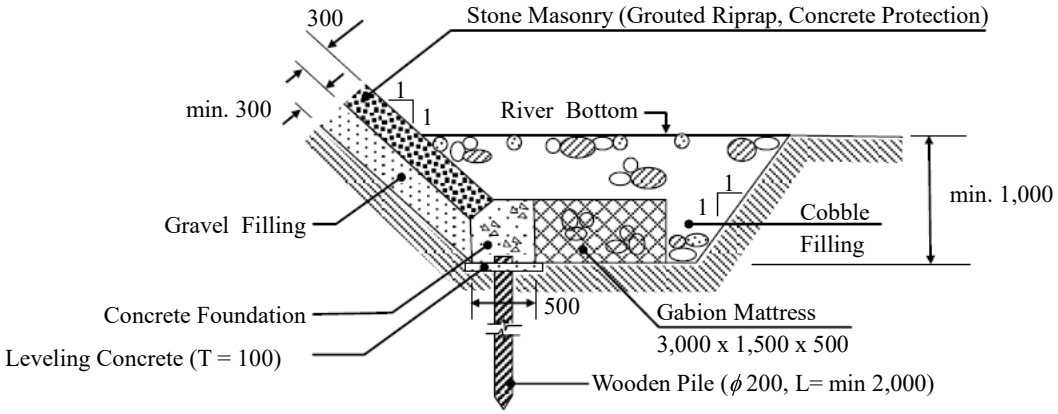


Figure AP 1.20.2 Foundation on Pile for Slope Protection Work

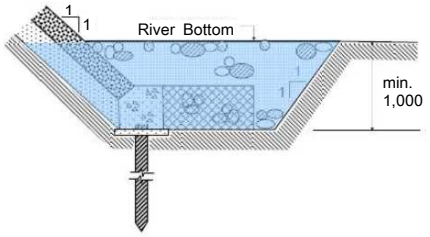
Bridge Repair Method

No.1-20	Slope Protection with Foundation Supported by Piles

3. Work Sequence

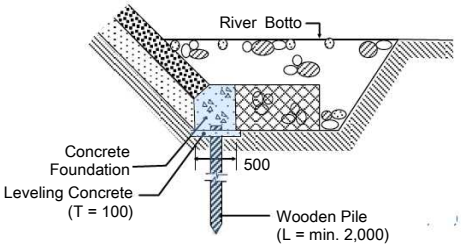
3.1 Excavation of Scoured Area

The damaged section of the existing slope protection shall be demolished, and the scoured section excavated in accordance with the alignment and depth shown on the drawings. The limit of demolition is marked on the existing protection. After excavation, the bed surface is compacted using lightweight mechanical or vibratory compactor.



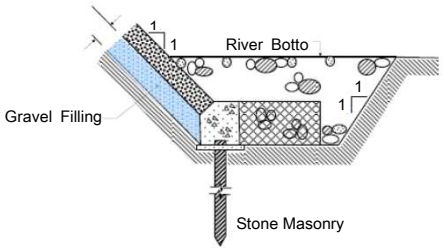
3.2 Placing Concrete Foundation

Wooden piles are driven at an interval of 1.5 m. When driven depth is achieved, excess protruding length is cut. Concrete foundation, provided with minimum reinforcements, is formed and casted above the piles. If river water exists, sand bags acting as cofferdam is provided during foundation works.



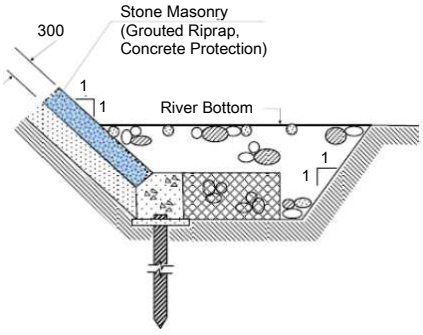
3.3 Compaction of Gravel Filling

Natural slope surface shall be properly compacted. Gravel filling for the masonry base is then placed and compacted using lightweight mechanical or vibratory compactor. A thickness of more than 300 mm, placed in 2 layers, is provided at the slope base.



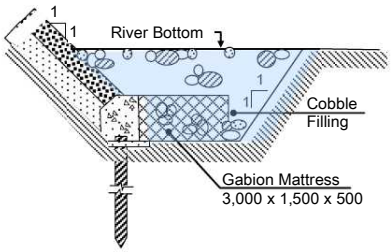
3.4 Placing Masonry

Appropriate masonry type will be selected from among variety of slope protection works such as stone masonry, grouted riprap and concrete masonry.



3.5 Installation of Gabion Mattress and Backfill

After filter fabric sheet is spread tightly on the bed, gabion mattress is installed in front of the concrete foundation as protection against local scouring and sliding. Finally, the excavated area and voids around the protection structure are backfilled with cobble stones, up to the level of river bed.



Bridge Repair Method

No.1-20	Slope Protection with Foundation Supported by Piles

4. Required Materials and Tools/Equipment

4.1 Required Material

- Gabion Mattress
- Rock Fill
- Wooden Pile
- Concrete with minimum steel reinforcements
- Filter Fabric Sheet (under gabion mattress)
- Backfill Materials
- Sandbag as cofferdam, when necessary

4.2 Required Tools/Equipment

- Vibratory compactor
- Backhoe

5. Measurement and Payment

5.1 Method of Measurement

The payment for the works shall be based on the total repair area, as identified by the Engineer.

5.2 Basis of Payment

The contract price paid per square meters for this work item should include full compensation for supplying all labor, materials, tools, equipment, and incidentals in performing all the works involving the preparation and completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

Bridge Repair Method

No.1-21	Gabion Mattress

1. Description of Repair Method

Local scouring around the pier often occurs due to strong stream flow, weak riverbed materials and type of foundation as shown in Figure AP 1.21.1. The worst damage that could occur due to scouring is the settlement of the bridge pier, eventually leading to undermining of the base and failure of the bridge. Thus, protection against local scouring is intended to eliminate or minimize future damage to the bridge substructure.

Figure AP 1.21.1 Local Scouring around Pier

2. Application Criteria

As a simple and effective repair method, gabion mattress is selected as protection for local scouring around bridge piers. The scoured area need to be excavated to a minimum 1.0 m depth for the gabion mattress installation. A filter fabric sheet should be laid under the mattress. From either edge of the pier shaft, the extending width of the upper mattress is ideally twice the estimated scour depth while three times for the lower mattress, as shown in Figure AP 1.21.2.

This criterion is only applicable as a standard repair method to damaged protection at small and medium rivers with a maximum discharge of 500 m^3/sec.

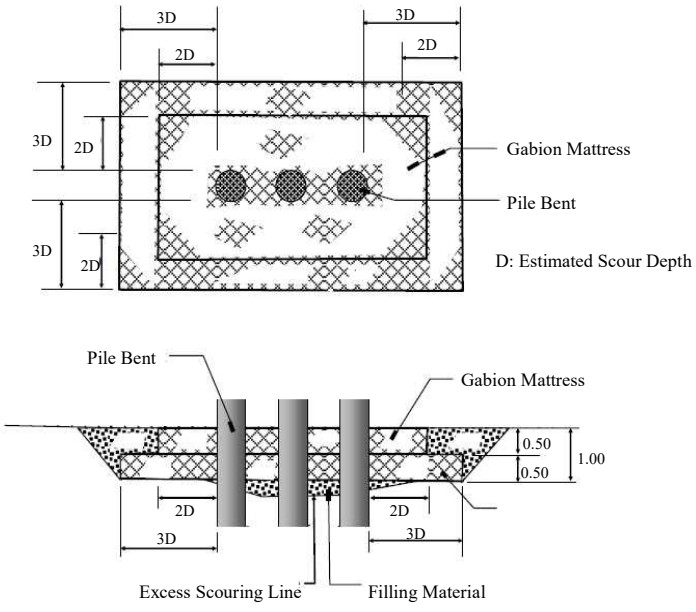


Figure AP 1.21.2 Application Requirement for Standard Gabion Mattress

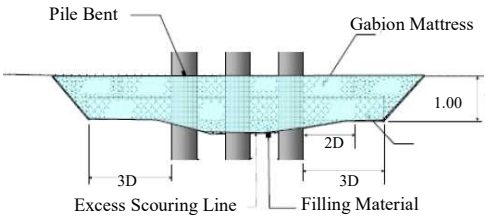
Bridge Repair Method

No.1-21	Gabion Mattress

3. Work Sequence

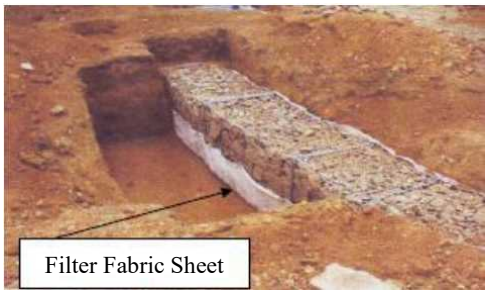
3.1 Excavation of Scoured Area

The scoured area around pier base is excavated in accordance with the alignment and depth indicated in the drawings. The actual excess scour section below the depth shown in the drawings is filled with selected material. After excavation, the bed surface is compacted using vibratory compactor.



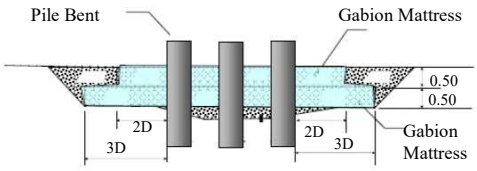
3.2 Filter Fabric Sheet Placing

The scoured area around pier base is excavated in accordance with the alignment and depth indicated in the drawings. The actual excess scour section below the depth shown in the drawings is filled with selected material. After excavation, the bed surface is compacted using vibratory compactor.



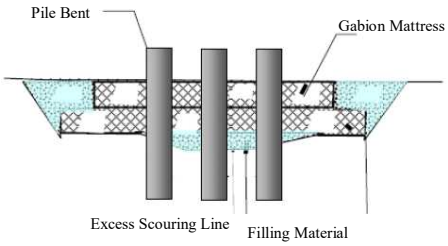
3.3 Installation of Gabions

Gabion filling shall be carried out by placing individual stone material into the gabion. When the gabion mattresses are completely filled, the cover panels shall be closed and the edges tied with binding wire as in a typical assembly process. The formed mattress shall be completely tight and square.



3.4 Backfilling

The backfill shall be placed evenly on all sides of the formed protection as appropriate. Each backfill layer shall extend to the limits of excavation or to natural ground.



4. Required Materials and Tools/Equipment

4.1 Required Material

- Gabion Mattress
- Rock Fill
- Wooden Pile
- Filter Fabric Sheet
- Backfill Materials

Bridge Repair Method

No.1-21	Gabion Mattress

4.2 Required Tools/Equipment

- Vibratory compactor

5. Specification

5.1 Construction Requirement

(1) Excavation and Backfilling

The base for the gabions shall be excavated to the required extent and level. The excess area around the finally formed gabion shall be backfilled. Each layer of backfill shall be compacted using an approved vibratory compactor.

(2) Filter Fabric Sheet Placing

The level where the filter fabric sheet is to be placed shall be thoroughly cleaned of debris, wood or any other foreign materials. The filter fabric sheet shall be spread tightly and pegged with material approved by the Engineer. The filter fabric sheet shall be placed with a 30 cm overlapping.

(3) Installation of Gabion

Where mattress are being assembled in position in a revetment, the binding of the edges of each mattress in the assembly process, and the binding together of adjacent mattress may be carried out simultaneously. The vertical corners shall be kept square and to full dimension by inserting a steel bar of at least 20 mm diameter at each vertical corner, maintaining the correct final position throughout the filling process. Edges of the mattress panels shall be tied with binding wire. The placing of individual stone material into the gabion shall be done by hand. In this case, the stones shall be bear on each other, and packed similar to dry random rubble masonry. No loose stones shall be placed into the mattress. Packing the outer layer and filling its interior with unspecified stones shall not be permitted. When the mattresses are completely filled, the cover panels shall be closed and its edges are tied with binding wire as in the usual assembly process. The formed mattress shall be completely tight and square, and in accordance with the dimensions, alignment and level shown on drawings.

(4) Backfilling

The backfill shall be appropriately filled up evenly on all sides of the mattress. Each layer shall extend to the limits of the excavation or to natural ground.

6. Measurement and Payment

6.1 Method of Measurement

The payment for repair works of gabion mattress shall be based on the total volume replaced to gabions, as identified by the Engineer.

Bridge Repair Method

No.1-21	Gabion Mattress

6.2 Basis of Payment

The contract price paid per cubic meters for this work item should include full compensation for supplying all labor, materials, tools, equipment, and incidentals in performing all the works involving the preparation and completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

Bridge Repair Method

No.1-22	Slope Patching

1. Description of Repair Method

Slope protection around the abutment is often damaged due to inadequate compaction of slope embankment, strong stream flow and insufficient flood drains. Although visible damage to the slope protection may be limited, voids may formed already under the protection due to the base failure. A large section of the slope protection, including the damaged portion, should be removed for purposes of patching repair.

Figure AP 1.22.1 Damaged Slope Protection

2. Application Criteria

Slope patching is an effective method that can be adopted to repair the limited damages on the masonry, during the early stage of visible defects. The area to be removed shall extend to a minimum of 500 mm around the perimeter of the damaged section. The protection bed should be excavated to a depth of 600 mm from masonry surface, as shown in Figure AP 1.22.2. New masonry patched into the excavated portion shall consist of 300 mm gravel filling and 300 mm masonry material as shown in Figure AP 1.22.3.

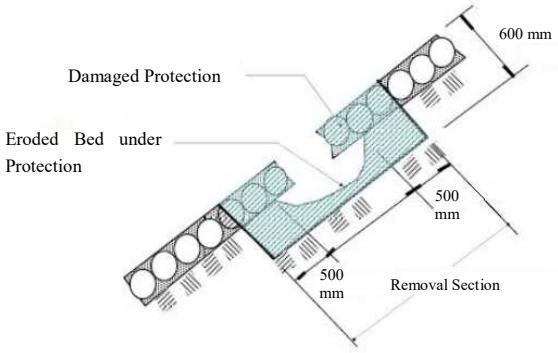


Figure AP 1.22.2 Typical Damaged Slope Protection

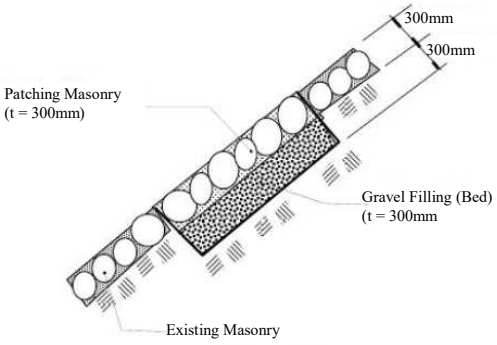
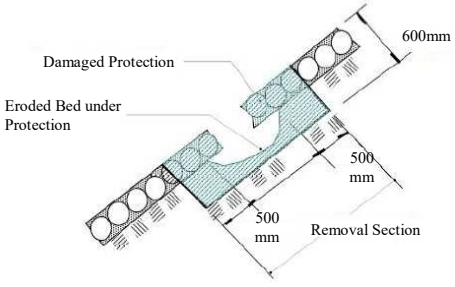


Figure AP 1.22.3 Slope Protection After Repair

3. Work Sequence

3.1 Removal of Damaged Protection

The damaged section of the existing slope protection shall be removed, and the scoured section excavated in accordance with the alignment and depth shown on the drawings. The limit of removal is marked on the surface of existing protection. After excavation, the bed surface is compacted using vibratory compactor.

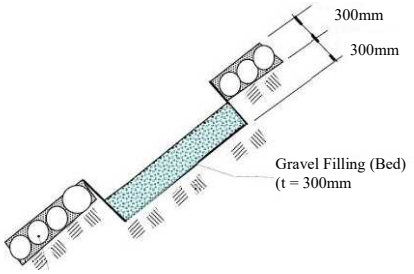


Bridge Repair Method

No.1-22	Slope Patching

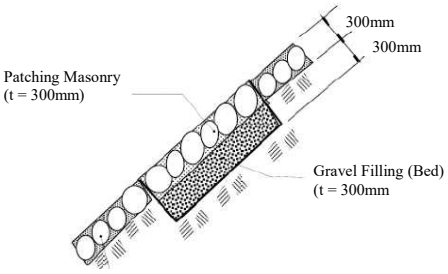
3.2 Compaction of Gravel Filling

Natural slope surface shall be properly compacted. Gravel filling for the masonry base is then placed and compacted using vibratory compactor. A thickness of more than 300 mm, placed in 2 layers, is provided at the slope base.



3.3 Patching Masonry

Appropriate masonry material will be selected depending on the type of existing masonry (stone masonry, grouted riprap and concrete masonry.)



4. Required Materials and Tools/Equipment

4.1 Required Material

- Masonry materials
- Crushed Stone

4.2 Required Tools/Equipment

- Vibratory compactor

5. Specification

5.1 Material Specifications

All materials required for the slope protection shall be in accordance with Standard Specifications of Lao PDR.

5.2 Construction Requirement

Construction requirements for the slope protection shall be in accordance with Standard Specifications of Lao PDR.

6. Measurement and Payment

6.1 Method of Measurement

The payment for slope protection works shall be based on the total area, as identified by the Engineer.

6.2 Basis of Payment

The contract price paid per square meters for this work item should include full compensation for supplying all labor, materials, tools, equipment, and incidentals in performing all the works involving the preparation and completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.

Bridge Repair Method

No.1-23	Nylon Fiber Gabion

1. Description of Repair Method

Due to strong river flow, local scouring surrounding bridge piers often occurs. The worst damage that could occur due to scouring is the settlement of the bridge pier, eventually leading to undermining of the base and failure of the bridge. Gabion Mattress shall be applied for this defect as standard repair method. But if river bed shape is complicated, it is very difficult to put Gabion Mattress. In this case, Nylon Fiber Gabion shall be adopted as appropriate selection for installation of anti-scouring protection. Thus, protection against local scouring is intended to eliminate or minimize future damage to the bridge substructure.

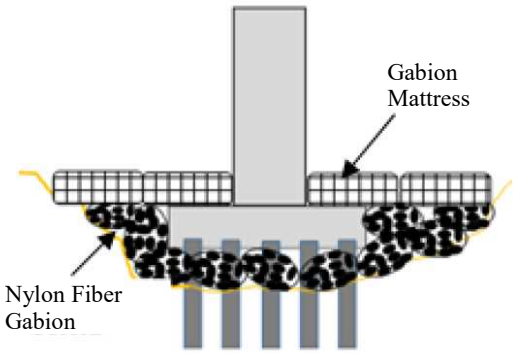


Figure AP 1.23.1 Local Scouring around Pier

2. Application Criteria

Nylon Fiber Gabion is used for prevention of scour on pier foundation and other underwater structures. It consists of a bag body formed by knitted fabric made of nylon. The bag is filled with boulders or stones which are also used for conventional box-type zinc-coated wire gabions. The nylon fiber gabion is flexible and conforms to the shape where it is placed. The nylon netting allows water passage through bag body ensuring that pressure of flowing water does not affect the bag and keeping the scour prevention materials (boulders) from being carried or swept away by the water.

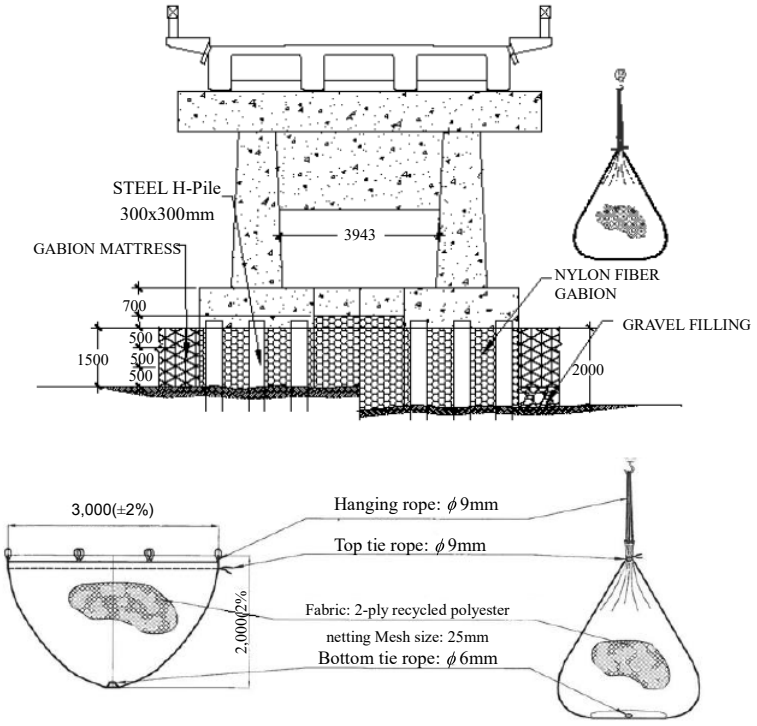


Figure AP 1.23.2 Application Requirement for Nylon Fiber Gabion

Bridge Repair Method

No.1-23	Nylon Fiber Gabion

3. Work Sequence

3.1 Place Boulders into Nylon Fiber Gabion Bag

When filled, Nylon Fiber Gabion weighs 2 tons with equivalent size of 3m x 2m and volume of about 1.24 m^3.

3.2 Transport to Scoured Area

After installation of boulders, Nylon Fiber Gabion shall be transported to scoured area by backhoe.

3.3 Place Nylon Fiber Gabion Using Backhoe

Using backhoe lay gabions in scoured portion. Continue laying up to designated elevation.

4. Required Materials and Tools/Equipment

4.1 Required Material

- Nylon Fiber Gabion
- Gabion Mattress
- Rock Fill (Boulders)
- Backfill Materials

4.2 Required Tools/Equipment

- Backbone or Crane

5. Specification

5.1 Material Specifications

Nylon Fiber Gabion bag materials shall conform to the requirements of the specifications shown in Table AP 1.23.1.

Bridge Repair Method

No.1-23 **Nylon Fiber Gabion**

Table AP 1.23.1 Specifications of Nylon Fiber Gabion Bag

Property	Test Method	Unit	Specifications
A. Tensile Strength			
1. Netting (25 mm mesh size)	ASTM D4268 / JIS A8960	N	≥ 450
2. Hanging Rope (9mm Ø)	ASTM D426 / JIS L2707	kN	≥ 10
3. Top Tie Rope (6mm Ø)	ASTM D4268 / JIS L2704	kN	≥ 7
4. Bottom Tie Rope (6mm Ø)	ASTM D4268 / JIS L2704	kN	≥ 7
B. Elongation			
1. Netting (25 mm mesh size)	ASTM D4268 / JIS A8960	%	≥ 30 to ≤ 50
2. Hanging Rope (9mm Ø)	ASTM D426 / JIS L2707	%	≤ 40
3. Top Tie Rope (6mm Ø)	ASTM D4268 / JIS L2704	%	≤ 45
4. Bottom Tie Rope (6mm Ø)	ASTM D4268 / JIS L2704	%	≤ 45

The material shall undergo quality tests and conform to the specifications above.

5.2 Construction Requirement

(1) Excavation and Backfilling

The base for the gabions shall be excavated to the required extent and level. The excess area around the finally formed gabion shall be backfilled. Each layer of backfill shall be compacted using an approved lightweight mechanical or vibratory compactor.

(2) Installation of Nylon Fiber Gabion

If scouring is heavily occurred, it is very difficult to apply to original gabion mattress underneath of pier footing. In this case, Nylon Fiber Gabion shall be applied for these locations as appropriate materials.

(3) Installation of Gabion Mattress

After installation of Nylon Fiber Gabion, gabion mattress shall be placed as surface layer.

(4) Backfilling

The backfill shall be appropriately filled up evenly on all sides of the mattress. Each layer shall extend to the limits of the excavation or to the natural ground.

6. Measurement and Payment

6.1 Method of Measurement

The payment for Nylon Fiber Gabion works shall be based on the total volume, as identified by the Engineer.

6.2 Basis of Payment

The contract price paid per cubic meter for this work item should include full compensation for supplying all labor, materials, tools, equipment, and incidentals in performing all the works involving the preparation and completely in place, as shown on the plans and as specified in the standard specifications, special provisions, and as directed by the Engineer.