



BRIDGE REPAIR MANUAL



EDITION 1



The Project for Strengthening of Capacity Development on
Bridge Management System in the Republic of Kenya



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This document has the status of a Manual. Users shall apply the contents there-in to fully satisfy the requirements set out.

The content of the manual is based on current practice in Kenya and latest practices in the road sector – locally, regionally and internationally.

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FOREWORD

The Government of Kenya through its Vision 2030, Kenya's long-term development strategy aimed at transforming the country into a middle income country, has prioritized infrastructure as a foundational enabler of the economic recovery strategies to re-position the economy on a steady and sustainable growth trajectory. In the 4th Medium Term Plan (2023-2027) of the Vision 2030 priority for an increased investments in improving infrastructure so as to lower the cost of doing business and improve national competitiveness and productivity have been identified as core themes for infrastructure development and management.

With full implementation of Performance Based Contracting (PBC) and continued funding from RMLF, there has been tremendous improvement in road maintenance in the Country. However, not enough attention has been paid to having a structured program that deals with maintenance of highway structures. Thus, the Bridge Management System (BMS) project was initiated to address management and repair of structures in Kenya. This is particularly important, as the structures form an integral part of the road network.

This manual gives guidance on how to carry out repair works on highway structures, for both preventive and reactive maintenance works. It is expected that all Road Agencies, Counties and other entities who manage road structures will make use of this manual to guide their repair works and employ value for money principles in structures maintenance and management. With this manual, the culture of preventive maintenance will be strengthened ensuring structures are in good conditions at all times, ensuring safety and uninterrupted connectivity.

This manual was developed by the Bridge Repair Sub-Working Group, constituted under the State Department for Roads with the assistance of the Japan International Cooperation Agency (JICA), through the BMS project. The membership of the sub-working group was drawn from State Department for Roads, MTRD, KeNHA, KURA, KeRRA, KRB, KWS, NCA and Japanese experts, whose contribution and dedication towards the development of this manual is acknowledged with appreciation.

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ABBREVIATIONS AND ACRONYMS

AC	Asphalt Concrete
BMS	Bridge Management System
CFP	Carbon Fibre Plate
CFS	Carbon Fibre Sheet
EN	European Standards
HTB	High Tension Bolt
JICA	Japan International Cooperation Agency
KeNHA	Kenya National Highways Authority
KeRRA	Kenya Rural Roads Authority
KIHBT	Kenya Institute of Highways and Building Technology
KRB	Kenya Roads Board
KURA	Kenya Urban Roads Authority
KWS	Kenya Wildlife Service
MoRT	Ministry of Roads and Transport
MTRD	Materials Testing and Research Directorate
NCA	National Construction Authority
NDT	Non-Destructive Test
NEMA	National Environment Management Authority
PBC	Performance Based Contracts
PC	Prestressed Concrete
PCM	Polymer Cement Mortar
PPE	Personal Protective Equipment
RC	Reinforced Concrete
SDR	State Department for Roads

DEFINITION OF TERMS

Abutment	Structural members located at both ends of a bridge that connects the embankment portion of the approach road to the bridge. It supports the load from the superstructure and retains the earth material.
Annealing	This refers to a heat treatment process used to modify the properties and structure of steel to improve its ductility, toughness and reduce internal stresses.
Annual Bridge Maintenance Action Plan	This is an asset management plan that contains bridge maintenance interventions, budget allocations and responsibility assignments within a road network. This plan should be structured in the format proposed in the ISO 55000.
Approach slab	It is a concrete slab installed behind the abutment that acts as an intermediate bridge to avoid abrupt changes in elevation or alignment.
Backwall/Curtain wall	The vertical wall at the ends of abutments that extends up from the bearing seat and supports the approach slabs, expansion joints and the embankment under the approach slabs.
Bearing	It is a device which transmits the vertical and horizontal actions from the superstructure to the substructure, and allows for movements between the superstructure and the substructure. Bearings allowing both rotation and longitudinal translation are called expansion/movable bearings, and those, which allow rotation, only are called fixed bearings.
Bridge	A structure, that can be accessed by traffic, with the function of aiding crossing over a waterway, road or any other obstacle. In the context of this manual, it also includes box culverts, viaducts and tunnels.
Bridge component	A bridge component is one of the three i.e. Principal Structure, Non-Structural Elements (NSE) and Road Furniture.
Bridge element	A bridge element is a part that acts to provide functionality, durability and safety requirements of a bridge which includes: superstructure, substructure or ancillary parts.
Coating	A layer applied to bridge elements to prevent corrosion and negative environmental effects.
Contractor	The entity engaged by the Employer through a due contract for the implementation of a supply, maintenance and/or repair assignment.
Corbel	It is a projecting wall member used as a support for some elements of the superstructure.
Cutback	A mixture of miscible liquids (petroleum and bituminous based liquids) used in construction, repair and maintenance of roads and bridges.

Damage	Defects due to external forces, e.g., flood, vehicle load, vehicle collision, earth pressure, vandalism etc.
Deck slab	A structural member that directly supports traffic passing through a bridge and transmits the load to the main girder (main structure).
Design working life	An assumed period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary.
Deterioration	Defects caused by changes in condition with age, e.g., carbonation, Alkali-Silica Reaction (ASR), salt damage etc.
Diaphragm	It is a bracing that connects main girders at the supports, to resist lateral actions and transfer loads to the supports. It locks the girders in place and also provides support to the deck slab.
Employer	The Employer is the procuring entity responsible for the road network in Kenya and who enters into a road/bridge maintenance contract with a contractor on a certain section of the road.
Emulsion	A mixture of immiscible liquids (water and bituminous based liquids) used in construction, repair and maintenance of roads and bridges.
Engineer	The representative of the Employer with responsibilities and obligations under the maintenance contract.
Environmental Management Plan	A plan developed to mitigate environmental impact of bridge Maintenance activities in compliance to NEMA regulations.
Epoxy	A type of polymer that when exposed to heat or chemical reactions hardens forming a compound with desirable engineering properties like adhesion, chemical and heat resistance, hardening, waterproofing and electrical insulation.
Expansion gap	A gap provided between a bridge girder and abutment or between discontinuous girders to allow expansion and contraction due to temperature changes.
Expansion joint	It is a device installed at the end of a girder or at the gap between girders to ensure smooth expansion and contraction and to allow automobiles and other vehicles to run smoothly on the bridge. It is mainly made of steel or rubber.
Foundation	The part of the substructure that transmits loads to the ground. Depending on the form, there are different types of foundations such as spread footing, pile foundations, and caisson foundations, etc. It transmits the loading from the substructure to the ground.
Implementers	The organizations involved in the inspections and maintenance/repair of bridges. In maintenance of bridges, the implementers are the road agencies, engineering consultants and contractors engaged in the construction, repair and maintenance of structures/roads.

Initial defects	Anomalies which were caused by design and/or occurred during construction (poor workmanship).
Input	Labour, materials, equipment and other supplies required to carry out the works.
Life Cycle Cost	This is an estimate of the cost that will be undertaken from the selected option of a structure or repair option during its service life. It includes the cost of planning, purchase, installation, operation, maintenance and decommission at the end of the structure service life.
Limit States	States beyond which the structure no longer fulfils the relevant design criteria.
Main girder/ Main structure	The main part of the superstructure, the structural member that supports all the loads acting on the bridge. In general, it is called the main girder in the case of girder structure, and the main structure in the case of truss or arch structure, etc.
Maintenance	The actions taken to keep the condition of a structural element to perform to its level of service.
Mobilization Period	The period required for the contractor to mobilize labour, equipment and materials for the commencement works.
Ninja-tech	The use of straps, ropes and other safety harness to inspect and undertake minor repairs underside of bridge and other hard to reach bridge members.
Obstructions	Accumulation of debris, driftwoods and stumps, rocks, silt, animals or anything that may impede free flow of water through a structure.
Painting	A layer of material applied on bridge elements for protective and/or aesthetic purposes.
Pier	A substructure member which supports the superstructure at intermediate points and transmits the load to the foundation.
Piles	A series of columns constructed into the ground transmitting loads down from the substructure for adequate support.
Policy Formulators	These shall be persons/entities responsible for making policies towards bridge repair and bridge maintenance.
Polymer	This is a long chain molecule made up of many repeating units. Polymer is added to mortar to improve the mortar performance.
Polymer Cement	Binders, compounds and aggregates mixtures that use epoxies, polyesters, vinyl-esters or other polymer resin bonds.
Polyurethane	This is an organic polymer that features many organic units linked via urethane molecules. Polyurethanes, often abbreviated to PU or PUR, are an immensely versatile class of polymers used in insulators, foams, elastomers, synthetic skins, coating and adhesives.

Rating Scale	This is a five stage condition status indicator for bridge elements as inspected. Deterioration rating shall be based on location, severity and element importance. This shall be assigned after detailed inspection.
Repair	This is the reinstatement of a damaged member or structure to its designed or as-built condition.
Safety Officer	Officer responsible for planning, implementing and overseeing health and safety on site.
Scaffolding	Temporary raised platform used to support workers, equipment and materials during construction works when the area being worked on is high/hard to reach from floor level.
Serviceability Limit States	States that correspond to conditions beyond which specified service requirements for a structure or structural member are no longer met.
Stakeholders	Person(s) with interest in the use and maintenance of bridges. They include the road agencies, engineering consultants, contractors, road users and the communities affected by the presence and usage of the bridge.
Stress relief annealing	An after treatment procedure of cast with the aim to reduce inner stress within the castings.
Substructure	Structural members that transfer the load from the superstructure, through the bearings, to the ground. It is a general term for bridge abutments, piers, and foundations.
Superstructure	Supports the weight of objects passing through the bridge and transmits it to the substructure. It consists of main girder, deck slab, cross beam, lateral bracing, diaphragms, etc.
Timber	Processed wood that is suitable for building of structures.
Ultimate Limit State	States associated with collapse or with other forms of structural failure.
Value Management	Value management is the technique concerned with maximisation of limited resources to achieve value for money.
Wingwall	The sidewall to the abutment backwall which is provided for to assist in confining the earth behind the abutment. The wingwalls can be monolithic with the backwall or disjointed.
Works	Combination of materials, skill and manpower and or equipment systematically executed as per the described methodology and in accordance with the Specifications for construction, repair, maintenance, strengthening, reinstatement and decommissioning of bridges.

1 INTRODUCTION

1.1 General Introduction

The purpose of this manual is to give guidance to implementers regarding maintenance and repair of bridges using available resources to ensure timeliness, value for money, safety, and uninterrupted connectivity for social economic development. It forms part of the Bridge Maintenance Manuals publications as shown in Table 1.1.

Table 1.1 Bridge maintenance manuals

S/No.	Document title	Document description	Category
1.	Inspection Manual for Bridges – Principal	Manual for all bridge inspections	Bridge Inspection
2.	Bridge Inspection Manual for ARBICS and PBC	Manual for routine and annual bridge inspections	
3.	Bridge Inspection Handbook	A pocket size guideline carried to site for bridge inspections	
4.	Bridge Repair Manual	Manual for bridge repair methodologies	Bridge Repair
5.	Standard Specifications for Bridge Repair in Kenya	Works specifications outlined in the Bridge Repair Manual	
6.	Cost Estimation Manual for Bridge Repair Works	Manual for cost estimation of bridge repair works	

It is considered that the manual can be used as a standalone reference book or it may be used in conjunction with other manuals herein referenced.

1.2 Contents of the Manual

This manual starts with a general introduction. It defines the rating standard and stakeholders involved in bridge maintenance. Chapter two describes the types of bridges, their elements and associated defects. The next chapter highlights various maintenance interventions applicable to various elements deterioration on various structures and outlines the possible repair methods.

1.3 Objectives

Overall objective

To describe and standardize bridge repair methodologies resulting into serviceable, safe and durable structures.

Specific objectives

- i. **To restore structural integrity and performance** – The manual seeks to outline repair methodologies to meet and extend the structures' serviceability.
- ii. **To limit deterioration** – The manual outlines means that can be used to prevent further deterioration that arise out of environmental conditions and usage.
- iii. **To incorporate new technologies** – The manual provides for new materials and innovative techniques in repair of defects.
- iv. **To employ value for money principles in structure maintenance** – The manual outlines cost optimization and evidence based decision making in maintenance of structures.

1.4 Scope Coverage

This Bridge Repair Manual shall cover the bridges within the Republic of Kenya that have been inspected and rated according to the bridge condition rating scale.

1.5 Expected Outcomes and Impacts

Outcomes

- ❖ This manual is a guide for maintenance and it stipulates ways and steps for implementing repairs.
- ❖ Reference document – general perspective for maintenance best practices while undertaking structures maintenance.
- ❖ Process document – it gives step by step procedures for undertaking repairs.

Impacts

- ❖ **Uniformity in implementation** – This manual shall ensure that all stakeholders implement bridge repairs in a standardized manner.
- ❖ **Standard operating processes** – This manual shall inform the SOP development in the various implementing agencies.
- ❖ **Knowledge enhancement document** – This manual shall contribute to knowledge and best practices in bridge repair.
- ❖ **Policy formulation framework** – This manual will inform a basis for development of principles of action to be adopted by stakeholder for bridge maintenance.

1.6 Quality Assurance and Quality Control

For the purpose of this manual, quality assurance shall refer to the process in bridge repair that focuses on improvement of repair quality, monitoring of repair process and audit of the same.

Quality control shall focus on tests that can be done on the repaired sections or repaired components to confirm function.

1.7 Bridge Condition Rating

Adoption of bridge condition rating scale

Introduction of condition rating – This manual adopts a five-point condition grading for bridges based on the bridge inspection assessed by these indicators: degree of damage, extent of damage, importance of the structure and urgency required to repair the observed deterioration or defect.

Local considerations – The manual outlines a bridge condition rating based on inspection, qualitative and element prioritisation.

Rating guidance – The rating guidance as shown in Table 1.2 is adopted.

Table 1.2 Bridge condition rating scale

Condition	Score	Rating	Damage Description	Action/Response Time
Stage 1	80 – 100	Very good	Bridge with minor durability or functional damages	Long-term action
Stage 2	60 – 79	Good	Bridge with moderate durability or functional damages	Mid/long-term action
Stage 3	40 – 59	Fair	Bridges with minor structural damages or extended durability or functional damages	Mid –term action (Requires preventive measures)
Stage 4	20 – 39	Poor	Bridge with moderate structural damages. Serious durability or functional damages	Short-term action (Requires prompt action)
Stage 5	0 – 19	Bad	Collapsed bridge or bridge with high-severity structural damages	Immediate urgent action (Require emergency measures)

Maintenance priority

Stage 1 – Observe or monitor.

Stage 2 – Low priority for repair.

Stage 3 – Repair before next inspection.

Stage 4 – High priority. Reduce inspection frequency time.

Stage 5 – Immediate action / replacement required.

Repair interventions

The repair interventions discussed below refer to initiatives on asset management that focus on planning and strategy management of the network level of the structure network. All design elements shall be done as per the relevant design standards by the Engineer.

1. Routine maintenance:

Maintenance work that is planned and performed on a routine basis to maintain and preserve the condition of the structure or to respond to specific conditions and events that restore the structures to an adequate level of service. This includes minor works that require basic tools and materials.

Routine maintenance should seek to increase the service life of the structure and its overall cost should be low. Below are some typical works for various categories of structures:

For steel superstructure:

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

For concrete superstructure/substructure

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

For protection works

- Removal of mud, sand and debris on the pier and abutment and cleaning of bridge seat and drainage pipe.
- Removal of drift wood materials.

2. Preventive maintenance:

Preventive maintenance may be condition based or planned (scheduled). It is the planned systematic implementation of cost effective treatments to an existing structure and its appurtenances that preserve the system, retards future deterioration and maintains or improves the functional condition of the road structure without increasing structural capacity.

Examples of preventive maintenance – bridge cleaning, deck sealing, sealing joints, thin deck overlays, removing large debris in channels, spot and zone painting and reconstructing/closing joints.

3. Restorative maintenance:

Restorative maintenance applies to maintenance activities that are performed as a reaction to deterioration of bridge elements. This work is performed on an as-needed basis rather than on a regular schedule. It is generally reactive rather than proactive and is different from planned preventive maintenance, which is generally performed in order to slow the rate of deterioration of a structure or one of its elements.

Examples of restorative maintenance: Painting (over coating and complete removal and re-coating), hydro demolition and rigid deck overlays, reconstructing/closing joints, superstructure repairs, substructure repairs, fatigue retrofitting, scour repairs, cathodic protection, and electrochemical chloride extraction.

4. Rehabilitation:

Rehabilitation involves major work required to restore the structural integrity of a bridge as well as work necessary to correct major safety defects. Rehabilitation projects can include component replacement (deck and or superstructure), repair or some

combination thereof. Rehabilitation must be conducted in conjunction with preservation practices that mitigate and slow the causes of the damage being repaired.

Examples of rehabilitation: Superstructure replacements, deck replacements, and culvert rehabilitation. Rehabilitation can include significant repairs that do not involve replacement of a bridge component. Examples include but are not limited to hydromilling with concrete overlay, structural beam end repair or strengthening or other significant improvements to bridge components.

5. Replacement:

Bridges that are structurally deficient, and/or are frequently overtopped are eligible for replacement or rehabilitation. A new structure is constructed and the existing defective structure is removed.

6. Emergency maintenance:

A reactive maintenance resulting from an observed or unexpected occurrence.

1.8 Stakeholders

This manual will be used as a guide by:

Policy formulators – To guide policy development for bridge repair and value for money principles for bridge maintenance.

Implementers – To outline best practices, materials and methods for bridge repair.

Trainers – Reference document for capacity building.

Contractors – For capacity building and work implementation guide for repair.

1.9 Competency of Maintenance Personnel

The works proposed in this manual should be undertaken by an implementer who possesses necessary and relevant knowledge, qualifications, skills, competencies as maybe required from time to time for BMS. and experience to handle the maintenance and repair works for the various bridge structures.

Skilled personnel trained by KIHBT and registered/accredited by NCA.

2. TYPES OF BRIDGES AND COMMON DEFECTS

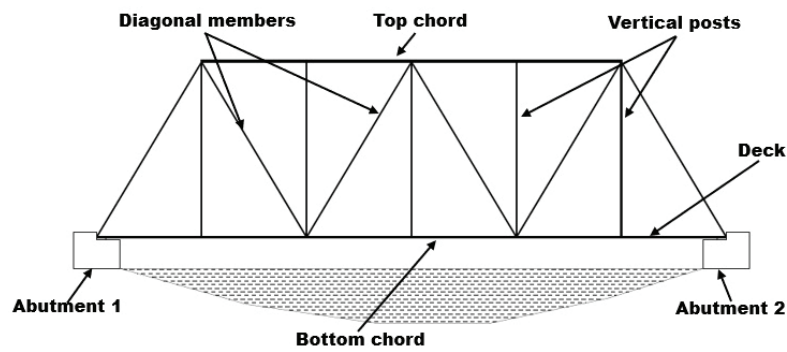
2.1 Introduction to Bridges

A bridge is a structure that carries a road, path, railway across a water way or any other obstacle. Table 2.1 shows the various types of bridges.

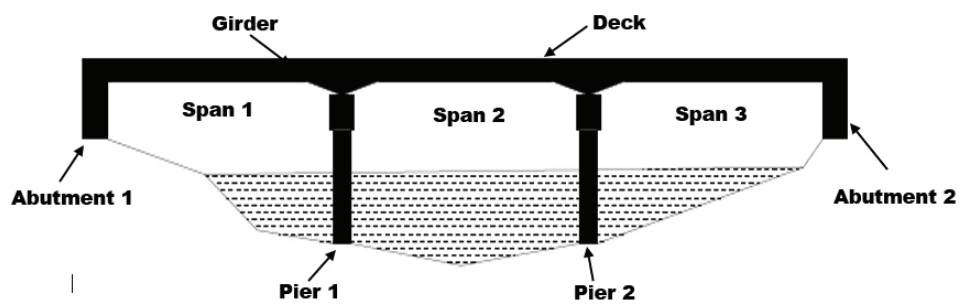
Table 2.1 Types of bridges

Image/Schematic
Arch bridge
Tied Arch

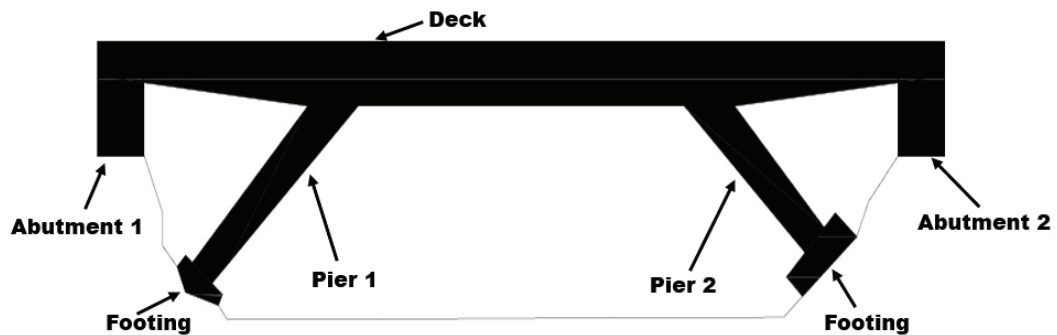
Image/Schematic



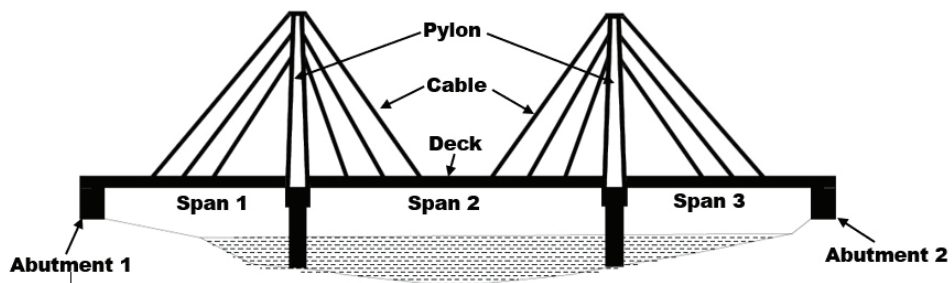
Truss



Beam/Girder

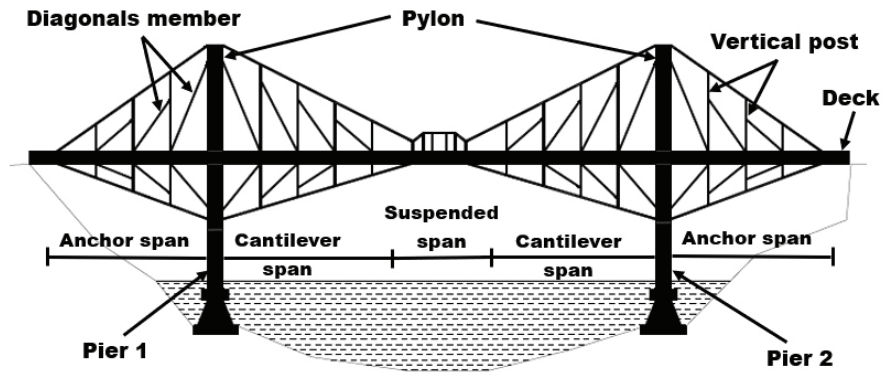


Rigid frame

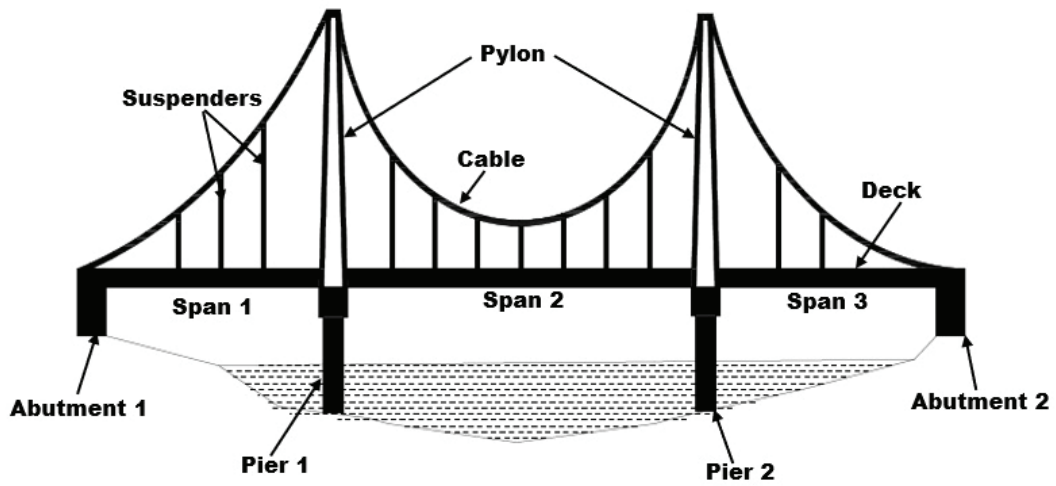


Cable stayed

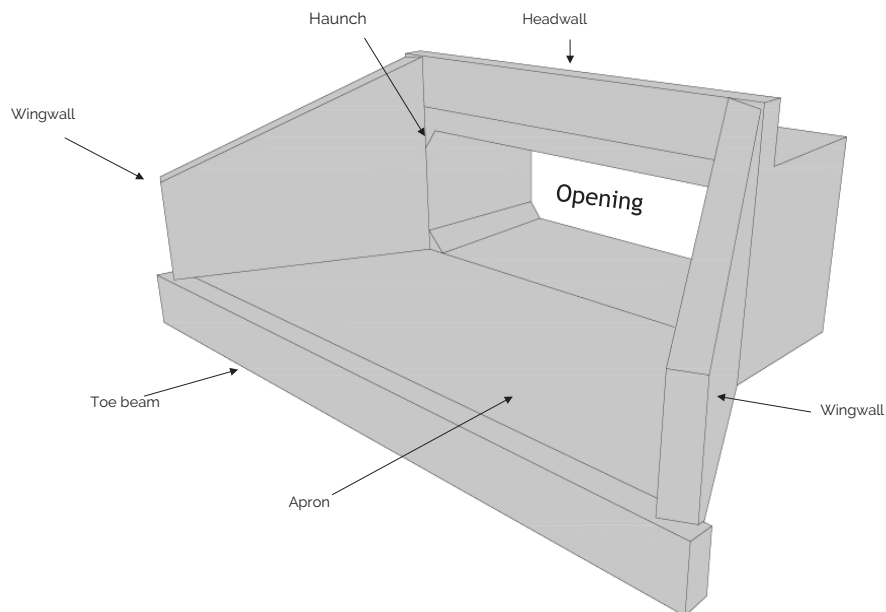
Image/Schematic



Cantilever



Suspension



Box culvert

2.2 Bridges in Kenya

In Kenya there are several bridges built for different types of crossings which include; waterways, railway lines, roads, pedestrians and animals crossings. The structures range from box culverts, footbridges, tunnels and bridges.

Notable road structures are as highlighted in Table 2.2.

Table 2.2 Notable road structures in Kenya

No.	Bridge Name	Details	Road Agency
1.	Mteza bridge	1440 m long, 47 spans, PC girder	KeNHA
2.	Mwache bridge	660 m long, 21 spans, PC girder	KeNHA
3.	Tsunza viaduct	690 m long, 46 spans, PC girder	KeNHA
4.	Makupa bridge	452 m long, PC I-girder	KeNHA
5.	Kilifi bridge	420 m long, PC box girder	KeNHA
6.	Nyali bridge	330 m long, PC box girder and RC girder	KeNHA
7.	Mtwapa bridge	192 m long, PC box girder	KeNHA
8.	Sabaki bridge	171 m long, PC box girder	KeNHA
9.	Mbita bridge	163 m long, truss and RC girder	KeNHA
10.	Gotu bridge	160 m long, 8 spans RC girder	KeRRA
11.	Masalani bridge	134 m long, suspension bridge	KeRRA
12.	Baricho bridge	241 m long, 7 spans, box girder	KeRRA
13.	Galana bridge	224 m long, 6 spans, bailey bridge	KWS
14.	George Adamson bridge	150 m long, 3 spans, bailey bridge	KWS
15.	Viaduct over Mumias and Kangundo roads	1000 m long, 40 spans, RC girder	KURA

There are several types of bridges depending on the material used in construction as shown in Table 2.3.

The choice of material depends on material availability, length of the bridge, cost and available technology during the design and construction period. Most of the timber and masonry bridges have now been replaced by concrete and steel bridges.

Table 2.3 Example of bridges by material and superstructure type

No.	Material	Superstructure Type	Examples
1.	Concrete	Girder	Kilifi bridge
		Arch	Athi River interchange
		Rigid frame	JKIA overpass
2.	Steel	Girder	Cabanas interchange
		Composite Girder	Kahiga bridge Bellevue footbridge
		Rigid Frame	Pangani footbridge
		Truss	Embobut bailey bridge Galana bailey bridge George Adamson bailey bridge
		Suspension	Masalani bridge Thua suspension bridge
3.	Masonry	Arch	Muringato bridge 1 and 2 in Aberdare National Park
4.	Timber	Beam	Kimothon bridge (Mt. Elgon) Rhodesia bridge (Tsavo West) Mzima springs (Tsavo West)

2.3 Common Bridge Defects

The following are the common bridge defects identified;

2.3.1 Common Defects on Concrete Bridges

Table 2.4 shows common defects on concrete bridges, their possible causes and proposed remedial measures. These defects can occur on the superstructure and substructure elements.

Table 2.4 Common defects on concrete bridges

Defects	Description	Image	Possible Causes	Remedy
1. Siltation	Accumulation of dirt, debris and unwanted materials. The presence of the unwanted material may cause growth of vegetation.		Blocked/ inadequate drainage. Leaking expansion joints.	Cleaning the affected area. Repair the underlying cause.

Defects	Description	Image	Possible Causes	Remedy
2. Corrosion	It is a gradual deterioration of re-bars caused by chemical reaction leading to the formation of iron oxides in the presence of moisture and oxygen. Formation of iron oxides around reinforcement bars leads to increase in volume of steel bars hence causing stresses in concrete. Corrosion can lead to loss of strength in concrete, fatigue and loss of bonding between steel and concrete.		Carbonation. Salt damage. Chemical attack.	Patching with rebar addition. Providing protection coating/mortar.
3. Cracks	It is a linear fracture in concrete that extends partly or completely through the member. Cracks may occur due to overload, structural deficiency, vehicle impact, thermal variation at different concrete layers or unanticipated structural action. Vertically aligned crack patterns in the vicinity of the mid-span of a beam and diagonal cracking at the ends can be indicators that cracking is of a structural nature.		Shrinkage. Stress. Rebar corrosion.	Seal the cracks. Member strengthening.

Defects	Description	Image	Possible Causes	Remedy
4. Spalling with rebar exposure	It occurs when a piece of concrete peels off from the main concrete member of a bridge and often leaves the reinforcement bars exposed. It may lead to corrosion of steel bars when exposed to adverse environmental conditions and degradation of structural members of the bridge hence affecting mechanical strength and durability.		Impact. Inadequate cover. Exposure to environmental conditions that lead to rebar corrosion.	Patching with rebar addition.
5. Spalling	It occurs when a piece of concrete peels off from the main concrete member of a bridge.		Impact. Inadequate cover. Exposure to environmental conditions that lead to rebar corrosion.	Plastering.

Defects	Description	Image	Possible Causes	Remedy
6. Scaling	It is the loss of concrete from the outer surface of concrete members due to weather effects or low quality of concrete grade used on a structural member.		Weather effects.	Application of fast setting mortar overlay.
7. Delamination	It occurs due to expansion in concrete resulting from corrosion in embedded reinforcement bars. Expansion in concrete may result into horizontal cracking or sub surface fracture in concrete at or just above the level of embedded reinforcement.		Exposure to environmental conditions that lead to rebar corrosion	Patching.

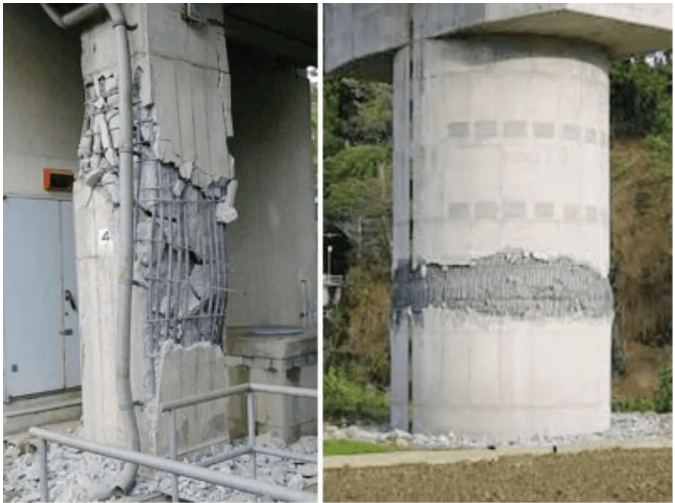
Defects	Description	Image	Possible Causes	Remedy
8. Honeycombing	These are voids in concrete or cavities in concrete arising from inadequate compaction of concrete during construction. They appear on the face of concrete or inside concrete. It may lead to exposure of aggregates and corrosion of steel reinforcement in harsh environmental conditions.		Inadequate execution during construction.	Patching or plastering.
9. Efflorescence	It occurs due to migration of salts to the surface of the concrete where they crystallize. It can sometimes be visible as crystalline deposits hanging from the soffit of the deck or beam.		Water penetration from the top. Cracks on the member.	Waterproof surface to prevent infiltration and unclog the drains. Crack sealing/ injection.

Defects	Description	Image	Possible Causes	Remedy
10. Carbonation	It occurs as a result of chemical reaction between Carbon (IV) oxide and Calcium Carbonate due to insufficient cover on structural concrete or porosity/voids in concrete leading to breakage of the protective layer around steel reinforcements. The loss of the protective layer leads to corrosion of the rebar and cracks in concrete appear due to the expansion pressure of the rebar.		Lack of concrete protective layer, exposure to carbon (IV) oxide in the atmosphere.	Patching. Provide surface coating to inhibit carbon dioxide ingress.
11. Chemical attack	It occurs when concrete is exposed to environmental conditions saturated with sulphur dioxide and nitrogen oxides. When precipitation occurs, acid rain is formed which could lead to chemical attack on bridge structures. Chemical attack may occur as a result of the following: - Acids - Salts and alkalis - Sulphate attack		Lack of concrete protective layer. Exposure to acids and sulphates.	Plastering. Provide protective coating/mortar.

Defects	Description	Image	Possible Causes	Remedy
12. Alkali Silica Reaction	It is a chemical reaction of alkali cations and hydroxyl ions in the pore solution of the hydrated cement paste that contain certain reactive silica phases present in the aggregates forming a gel that absorbs water and expands, cracks appear in the concrete. As the ASR progresses, the cracks gradually spread to the surface of the concrete forming alligator cracks.		Concrete aggregates containing alkali reactive minerals.	Plastering. Provide protective coating/mortar.
13. Salt attack	Salt attack on concrete occurs when soluble salts containing chlorides found in fertilizers, ocean water, marine air reacts with concrete destroying the passive film making the steel bars in the concrete expand due to corrosion, resulting to spalling.		Lack of concrete protective layer against salt from the sea.	Patching. Provide protective coating/mortar to inhibit chloride ions ingress.

Defects	Description	Image	Possible Causes	Remedy
14. Abrasion	It occurs when concrete surfaces are unable to resist wear and tear caused by external forces exerted by traffic and hydraulic effects.		Impact of erosive river action. Wear and tear from traffic.	Plastering.
15. Leakage	This is the presence of unwanted passage of water on concrete elements due to lack of proper waterproofing material, presence of cracks, poor drainage and failing joints.		Leaking crack.	Repair the concrete fill in part between the girders. Waterproof top of deck slab. Crack injection/sealing.

Defects	Description	Image	Possible Causes	Remedy
16. Leaching	Seepage of water through cracks and voids in hardened concrete which may dissolve Calcium Hydroxide and other constituent materials in concrete. It can be evident in the form of staining, efflorescence and encrustation at cracks.		Water penetration.	Waterproofing top surface of member/inner surface. Crack injection/sealing.
17. Excessive deformation /deflection	Excessive deflections occur as a result of creep, over loading, inadequate design, poor construction techniques or failure in material performance.		Fatigue or overloading.	Carry out concrete strengthening works. Limit heavy trucks using the bridge. Reconstruct the bridge.

Defects	Description	Image	Possible Causes	Remedy
18. Discoloration	This occurs when water penetrates through the deck surface down to the columns, beams, abutments and piers, causing a brown discoloration of the members. This is usually caused by poor drainage on the deck surface.		Smoke from illegal human activities. Leaking joints.	Cleaning the affected area. Covering with protective coating/mortar.
19. Buckling	It occurs when a slender column/beam fails due to excessive compression along its length. The member thus fails when subjected to high compressive stresses, where the actual stresses at failure are smaller than the ultimate compressive stresses that the member can withstand.		Inadequate design and execution.	Concrete strengthening/replacement of member. Provision of reinforcing members.

2.3.2 Common Defects on Steel Bridges

Table 2.5 shows the common defects on steel bridges, their possible causes and proposed remedial measures. These defects can occur on the superstructure and substructure elements.

Table 2.5 Common defects on steel bridges

Defects	Description	Image	Possible Causes	Remedy
1. Siltation	Accumulation of dirt, debris and unwanted materials which may cause growth of vegetation and blocking of drainage structures.		Rising water levels during flood, sediments deposited. Leaking joints. Drainage pipes discharging directly to the steel members.	Clean off the sediments. Clear the river channel of any debris. Check the drainage system provided and repair accordingly.
2. Corrosion	Corrosion of steel members occurs when these members are exposed to environmental conditions such as high salinity and moisture. Corrosion leads to substantial reduction in member capacity and is the primary cause of sectional loss in steel members. It is prevented by applying a protective coating such as paint on the steel member to prevent exposure to environmental conditions.		Worn out/damaged protective paint.	Clean and apply protective paint.

Defects	Description	Image	Possible Causes	Remedy
3. Paint peel-off /Deterioration of corrosion protection	Painting shields steel from water and oxygen by covering it, thereby preventing corrosion. Paint peel off occurs when paint on a section of the steel member loses its adhesive properties hence leading to the reduction of the protective layer. The paint film deteriorates over time, and if the paint is not reapplied at the appropriate time, the corrosion protection function will deteriorate.		Loss of bond between the protective layers.	Remove the paint, apply primer and protective paint layers.
4. Heat Damage	This is the weakening of steel members as a result of exposure to fire or extreme heat. As a result of these exposures, the members undergo serious deformations such as sagging, elongation, buckling and twisting. Rivets and bolts may also fail at connection points.		Fire outbreak.	Reinforce the member or replace. Protect with fire resistant coating.

Defects	Description	Image	Possible Causes	Remedy
5. Sectional Loss	This is the reduction in cross-sectional area of a steel member caused by corrosion or wear and tear on steel structure elements. This sectional loss causes reduction in load carrying capacity of the member.		Corrosion of the member.	Replace member. Clean by blasting, provide additional strengthening plate and reapply protective paint.
6. Missing Parts	This occurs when some bridge members are lost due to vandalism or failure of bridge members in the case of adverse environmental conditions such as earthquakes and floods.		Vandalism of steel parts. Vibrations on the bridge. Inadequate execution during construction.	Replace the missing parts and weld bolt-ends.

Defects	Description	Image	Possible Causes	Remedy
7. Cracking	Cracking of steel members occurs in a structure resulting from fatigue usually occurring at points of tensile stress concentrations, at welded attachments or at termination points of welds.		Fatigue.	Provide stop-hole at the end of crack to stop the crack from propagating. Strengthen section/ replace.
8. Fracture	Fracture is the breaking of steel due to fatigue or impact.		Fatigue, stress or impact.	Strengthening the fractured member. Replacing with a new member.
9. Excessive vibrations and noise	Excessive vibration is caused by excessive loading on bridge structure and often indicates occurrence of failure in bridge connections and steel members.		Excessive stress/fatigue.	Reinforce cracked or fractured members. Replace members.

Defects	Description	Image	Possible Causes	Remedy
10. Deformation and deflection	Deformation results from impact loading on bridge members while deflection is caused by long-term loading on the bridge structure. It results into cracking on other members in case of transfer of excessive stresses.		Overloading. Impact.	Reinforce member. Replace the affected member.
11. Buckling	Buckling occurs when a slender structural member is exposed to high compressive stresses that result in a sudden sideways deflection. Kinking is the loss of or twist in shape of a bridge member as a result of long term loading. Warping occurs when the twisting of a member results in the cross-sections distorting out-of-plane along the direction of the member's longitudinal axis. Most cold-formed members (i.e. all except closed hollow circular sections) have cross-sections which tend to warp when subject to torsion.		Impact due to accident. Overloading. Inadequate member size.	Reinforcing the member. Replacing the member. Limit the weight of vehicles using the structure.

Defects	Description	Image	Possible Causes	Remedy
12. Loose/ Missing Bolts	This occurs as a result of actions/loading on bridge members connected using structural bolts. Loose bolts may also be as a result of incorrect installation, vandalism, excessive vibrations, corrosion of the connector plates or fasteners, overstressing, cracking or failure of individual fasteners. Factors leading to failure include lack of routine inspection and maintenance on steel bridge structures.		Vibrations. Poor workmanship Vandalism.	Replace missing bolts. Sensitization against vandalism.
13. Accumulation of water	This is the ponding of water on steel members as a result of depressions on steel deck caused by excessive deflection, failure of vertical members and no drain function.		Inadequate drainage facility. Clogging of drainages.	Provide suitable drainage. Clean the blockages on the drains.

Defects	Description	Image	Possible Causes	Remedy
14. Discoloration	This occurs when water penetrates through the deck surface onto the columns and beams below, causing a brown discoloration of the members.		Human activities. Leaking joints. Poor drainage.	Clean and repaint the sections affected. Repair the leaking joints.

2.3.3 Common Defects on Timber Bridges

Table 2.6 shows the common defects on timber bridges, their possible causes and proposed remedial measures. These defects can occur on the superstructure and substructure elements.

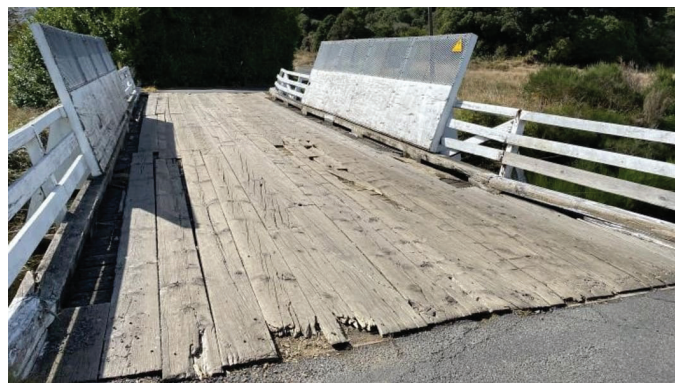
Table 2.6 Common defects on timber bridges

Defects	Description	Image	Possible Causes	Remedy
1. Siltation	This is the build-up of dirt and vegetation on the timber structure. The presence of the siltation encourages wetness hence has an influence on the drying and equilibrium moisture content of the timber and can hasten cracking and deterioration of timber.		Deposition by traffic and elements.	Clean regularly.

Defects	Description	Image	Possible Causes	Remedy
2. Rotting	This is the attack of timber by fungi when the moisture content of the timber is above 20% and there is presence of air and warmth for the growth of fungi.		Water leakage. Dampness.	Repair/improve the drainage system around the timber elements. Application of fungicide when the timber is drying. Apply chemical preservative to timber. Replace damaged sections.
3. Termite attack	Termites eat the sapwood and heartwood of the timber affecting its quality and strength.		Use of untreated timber. Area with active termites. Fungal rotting.	Inject termite poison into the timber. Installation of pile jackets.

Defects	Description	Image	Possible Causes	Remedy
4. Loose connections	This is weakening on timber connections after long term loading and exposure to environmental serviceability and vibrations.		Inadequate execution. Vandalism. Excessive movements under loading. Shrinkage of timber around connections.	Tighten the existing bolts. Replace loose connections.
5. Cracking	Fractures due to loading, particularly in flexural (bending) members.		Overloading. Inadequate member due to span. Ineffective supports.	Control/limit the traffic using the bridge. Replace timber member with adequate section. Strengthen the timber member with additional member.

Defects	Description	Image	Possible Causes	Remedy
6. Splitting	This is when the crack progresses all through the timber hence separating the timber into two.		Overloading. Inadequate member due to span. Ineffective supports.	Replace member. Strengthen member.
7. Missing member	This occurs when some bridge members are lost due to vandalism or failure of bridge members.		Rotting. Vandalism. Excessive vibrations. Overloading. Traffic impact.	Replace missing member.

Defects	Description	Image	Possible Causes	Remedy
8. Discoloration	This is the coating of the original surface of the timber with an unwanted material.		Traffic action. Human activities. Poor drainage/ Leaking areas.	Apply suitable coating if unsightly. Improve drainage.
9. Abrasion	This is the mechanical wear and loss of section from traffic effects on deck timbers, which sometimes results in an undesirable slipperiness.		Traffic action.	Replace damaged section. Provide measures to prevent or reduce the abrasion of the timber members.
10. Excessive deflection	This is abnormal lateral displacement of a timber member when it is loaded laterally, manifested by a curve along its longitudinal length which may affect its serviceability or functionality.		Overloading. Inadequate member due to span.	Control the traffic using the bridge. Strengthen/ replacing the timber member

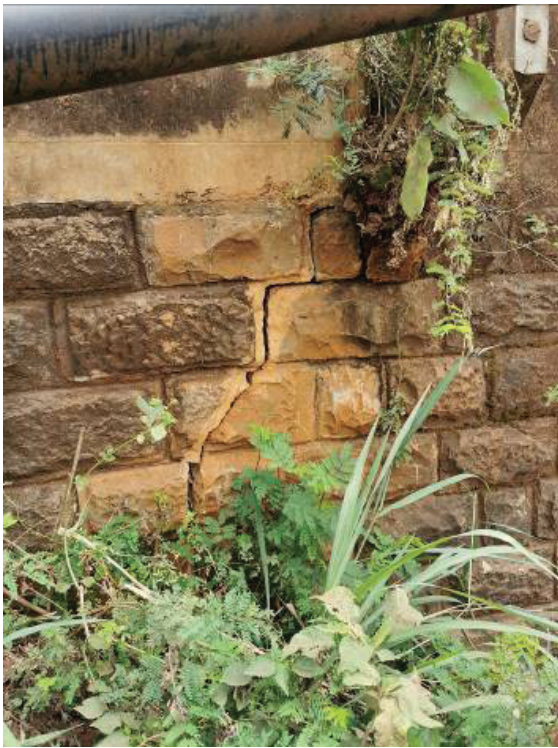
2.3.4 Common Defects on Masonry Bridges

Table 2.7 shows the common defects on masonry bridges, their possible causes and proposed remedial measure. These defects can occur on the superstructure and substructure elements.

Table 2.7 Common defects masonry bridges

Defects	Description	Image	Possible Causes	Remedy
1. Siltation	This is the accumulation of dirt or debris on the components of the bridge.		Deposition by river action, and elements. Human/animal action.	Clean regularly. Discourage dumping.
2. Loss of masonry blocks	This is the loss of masonry block(s) on the bridge elements.		Water penetration. Bond failure. Vandalism. River action. Impact	Replace the lost bricks/blocks.

Defects	Description	Image	Possible Causes	Remedy
3. Efflorescence	This occurs when salt laden water seeps into the mortar joints, resulting to visible salt deposits at the mortar joints.		Water penetration from the back of the masonry wall. Cracks on the mortar/mortar deterioration.	Clean the weepholes provided. Provide suitable weepholes. Repair the cracks.
4. Cracks	These are fissures/openings on the masonry members. The cracks may form on the mortar joint and/or on the masonry itself.		Settlement. Earth pressure. Impact.	Repair the cracks. Replace the cracked section/element.

Defects	Description	Image	Possible Causes	Remedy
5. Vegetation growth	This is the growth of vegetation on/near the masonry elements of the bridge. The growth of vegetation may lead to further damage to the masonry walling.		Presence of cracks. Sediments and moisture.	Clear all the vegetation and the organic sediments regularly. Repair the cracked/damaged areas.

Defects	Description	Image	Possible Causes	Remedy
6. Discoloration	This is the change in color of the masonry caused by dampness, chemical attack or even impurities in the environment like smoke from traffic.		Human activities. Dampness. Animal action.	Cleaning. Coat with protective material the exposed surfaces.
7. Scour	Scour is the erosion of the channel bed. Scour is critical if it occurs adjacent to the footings.		Erosive water action.	Fill and provide suitable protection.
8. Bulging of masonry wall	This is the movement of masonry unit relative to each other in a transverse direction. The movement can cause cracking and loss of mortar.		Earth pressure from moist back fill. Compaction of fill material by traffic loading.	Repair/replace the damaged section. Provide weep holes to drain water from the back fill.

Defects	Description	Image	Possible Causes	Remedy
9. Mortar Deterioration	This is the weathering of the mortar joint leading to cracking, crumbling, chipping away and/or discoloration of the joint mortar.		Water action. Wear and tear.	Replace the deteriorated mortar joint. Protect the masonry surface with suitable coating material.

2.3.5 Common Defects on Ancillary Elements

Tables 2.8 to 2.11 shows the common defects on bridge ancillary elements, their possible causes and proposed remedial measures.

Table 2.8 Common defects on railings and parapets

Defects	Description	Image	Possible Causes	Remedy
1. Fracture	This is the breaking of steel members of the steel railings.		Impact or hit by the road users. Corrosion. Inadequate execution. Vandalism.	Weld back the fractured member and reinforce. Replace the member with adequate type.

Defects	Description	Image	Possible Causes	Remedy
2. Corroded railings and parapet walls	Steel railings are susceptible to corrosion when the antirust protective layer is worn out.		Worn out or lack of protective paint.	Prepare steel surface, apply primer and protective paint. Member replacement.
3. Discoloration	This is the change in colour on surfaces of railings as a result of corrosion, aging on paint coating, defacing of members.		Corrosion. Aging of paint coating. Vandalism.	Clean surface and protect the surface with suitable coating.

Defects	Description	Image	Possible Causes	Remedy
4. Cracked railings and parapets	Cracks can appear on the steel railings and RC parapet walls.		Shrinkage. Stress. Workmanship or use of unsuitable material. Impact.	Provide reinforcing member or replace the member for steel members. For steel members, strengthen the section or replace the steel members. Provide the expansion gap for some of the cases. For RC members, repair the crack using an appropriate method depending on severity of the crack.
5. Missing parts	This is the loss of bolts, sections, rivets and anchorages.		Vandalism. Impact.	Replace the missing part.

Defects	Description	Image	Possible Causes	Remedy
6. Loose connections/ missing bolts	This is weakening on steel connections after long term loading and exposure to environmental serviceability and vibrations.		Inadequate execution. Vandalism. Accidental knocking. Excessive vibrations.	Tighten the loose bolts and nuts. Replace the missing bolts and weld the bolt ends.
7. Deformation	This is the change in shape on members or parts of the bridge as a result of accidental knocking by traffic or forces of nature.		Impact by the road users.	Replace the deformed members.
8. Spalling on the reinforced concrete parapets	This is when a section of concrete peels off from the main member and can leave the reinforcement bars exposed.		Impact by the road users. Corrosion of reinforcement.	Section repair the spalled area. If the rebars are corroded apply antirust before repairing with concrete.

Table 2.9 Common defects on drainage

Defects	Description	Image	Possible Causes	Remedy
1. Broken drain pipes	This is the collapse or splitting of the drainage pipe.		Impact. Workmanship. Fire.	Replace the broken drain pipes.
2. Clogging	This is the accumulation of debris on inlet of the drains and/or the drain pipes.		Siltation and sedimentation. Workmanship.	Clear all the debris clogging the drains regularly.

Defects	Description	Image	Possible Causes	Remedy
3. Corrosion	Sections of the drainage can corrode and lead to functional loss.		Exposure to elements.	Replace steel member. Provide measures to protect against corrosion. Replace section with non- corroding material.
4. Missing drain cover	Absence of drainage covers that were previously provided.		Vandalism. Corrosion. Accidental damage by traffic.	Replace drain cover. Replace drain cover made of non steel materials.

Defects	Description	Image	Possible Causes	Remedy
5. Root intrusion/ Vegetation growth	This is vegetation growth on the drains and/or intrusion of roots.		Sedimentation and ponding of water on the drainage system. Inadequate slope.	Regularly clean the drainage system of unwanted material.
6. Missing drainage facilities	Missing drainage facilities.		Inadequate design.	Provide alternative drainage.

Table 2.10 Common defects on embankment protection

Defects	Description	Image	Possible Causes	Remedy
1. Surface deterioration	Loss of stones and/or mortar on the provided slope protection works.		Erosive river action. Accident impact. Vandalism.	Repair the deteriorated slope protection. Provide a support toe at the bottom of the slope protection.

Defects	Description	Image	Possible Causes	Remedy
2. Embankment erosion	Erosion of the embankment soil material leading to the development of trenches.		Surface water run-off. Animal foot action.	Provide suitable slopes of the embankment. Provide suitable slope protection works. Provide scour checks.
3. Unwanted vegetation	This is growth of unwanted vegetation near the bridge structure which could lead to damage on the bridge abutment and slope protection work.		Uncontrolled growth of vegetation on the embankment.	Regular vegetation control on the embankment.

Defects	Description	Image	Possible Causes	Remedy
4. Damaged gabion protection	The gabion wire can be torn or the hardcore inside the boxes missing		Vandalism. Erosive river action.	Repair the gabion protection appropriately. Grout the exposed surfaces after repair.

Table 2.11 Common defects on signalling

Defects	Description	Image	Cause	Remedy
1. Faulty or missing lightings	The lighting can be missing or not functioning and therefore not providing light in the required areas.		Electrical problems. Corrosion. Impact. Vandalism.	Repair the electrical issues. Carry out corrosion protection to the areas affected by corrosion. Replace the missing lighting poles complete with fittings.

Defects	Description	Image	Cause	Remedy
2. Missing road signs	Signage should be available to inform the road users about the safe use of the bridge/road.		Vandalism. Impact by vehicles. Wear and tear. Poor quality materials.	Replace the missing road signs.

2.3.6 Common Defects on Other Structural Components

Tables 2.12 to 2.19 show the common defects on other bridge structural components, their possible causes and proposed remedial measures.

Table 2.12 Common defects on pavement/surfacing

Defect	Description	Image	Possible Causes	Remedy
1. Cracks on the pavement	This refers to cracking on the pavement/surfacing on the deck slab due to excessive loading on the bridge structure.		Stresses caused by overloading.	Crack sealing and pothole patching.

Defect	Description	Image	Possible Causes	Remedy
2. Rutting	It occurs along the wheel path and results from the accumulation of load-induced permanent deformation developed by the pavement layer.		Repeated heavy wheel loading. Pavement depth and material.	Mill and replace with suitable pavement.
3. Loss of skid resistance	This is loss of sufficient grip/ friction needed for traffic movement on the bridge deck. It can be attributed to wear and tear due to traffic whip off and traction forces on tires.		Tear and wear caused by traffic.	Provide a wear-ing course.

Defect	Description	Image	Possible Causes	Remedy
4. Siltation	This is the deposition of soil sediments on the pavement where they are undesirable.		Deposition of soil and other solid materials by the road users, surface water or wind. Inadequate drainage system on the bridge.	Regular cleaning of the pavement and drainage.
5. Potholes	Potholes occur when parts of a road surface gets damaged through cracking or wear forming depressions.		Ingress of water into the pavement. Deterioration of pavement layers. Impact on pavement. Fire.	Repair potholes and ruts by patching with AC.

Table 2.13 Common defects on foundations

Defect	Description	Image	Possible Causes	Remedy
1. Settlement	This is the vertical movement of a foundation. This can be determined by cracks formed on the structure components supported by the foundation.		Inadequate foundation design. Lack of embankment protection.	Provide proper protection of soil around abutments and piers. Underpin the foundation. Reconstruct the settled section.
2. Lateral movement	This is the horizontal movement of a foundation, this mostly happen when the abutment or pier is constructed on a slope or near river bed.		Inadequate foundation design. Lack of embankment protection.	Provide proper protection of soil around abutments and piers. Underpin the foundation. Reconstruct the settled section.

Defect	Description	Image	Possible Causes	Remedy
3. Scouring	This occurs when material carried by moving water rub against the foundation material causing tear and wear on the foundation.		River action. Vandalism. Animal action.	Provide suitable slope protection works. Lining the river channel.
4. Sapping	This is the wearing off of material beneath the foundation of a structure leaving a space between the foundation and the ground.		Scouring by running water.	Provide protective measures e.g. Gabions under the foundation. Lining the river channel.

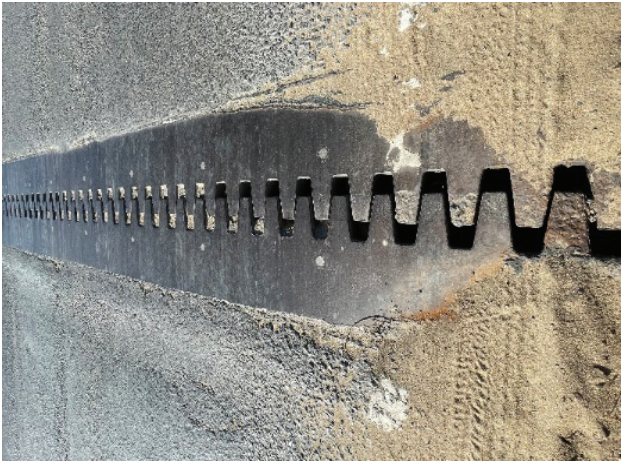
Table 2.14 Common defects on bearings

Defect	Description	Image	Possible Causes	Remedy
1. Breakages	This is the separation of the bearing from its original structure/location.		External forces like overloading and earthquakes. Inadequate design. Workmanship.	Partial repair/replacement with a new bearing.
2. Siltation	This is the accumulation of solid material on the bearings, this may provide conducive environment for corrosion. The debris deposited on the bearings can also hinder the movement of the bearings.		Leaking joints. Sedimentation during flooding. Animal activity/elements.	Regular cleaning of the bearing seat area. Repair the leaking joints.

Defect	Description	Image	Possible Causes	Remedy
3. Corrosion	This is the slow degradation of the steel bearings where the metal surface is oxidized thus leading to sectional loss.		Exposure to environmental factors that encourage corrosion. Accumulation of silt and/or moisture around the bearing. Deterioration of protective paint.	Prepare surface, apply primer and protective paint. Seal leaking joints. Clean the silt around the bridge seat.
4. Cracks on the bearing seat mortar.	These are cracks that develop on the mortar provided as the bed for the bearings.		Corrosion. Stress due loading. Tear and wear.	Repair the bearing seat.

Defect	Description	Image	Possible Causes	Remedy
5. Deformation of elastomeric bearings	Faults include splitting, tearing or cracking of the outer casing and even bulging and distortion.		Deterioration of elastomeric material. Excessive shear force. Separation of composite pad laminations. Uneven compression and twisting of the bearings,	Replace the deformed bearing.
6. Loose/Missing bolts and nuts	Anchoring bolts may be loose or missing. This may cause excessive movements at the joints.		Vibrations. Vandalism. Workmanship.	Tighten loose bolts and nuts. Replace the missing bolts and nuts.

Table 2.15 Common defects on bridge expansion joints

Defect	Description	Image	Possible Causes	Remedy
1. Fracture	This is the breaking of section(s) of the expansion joint.		Fatigue. Impact by road users. Vandalism. Corrosion of the steel members. Movements of the spans.	Replace the fractured section or whole device. Address the cause of the defect to prevent reoccurrence after repair.
2. Corrosion	This is the slow degradation of the steel joints where the metal surface is oxidized thus leading to sectional loss.		Worn out protective layer. Exposure to elements in the environment favouring corrosion. Ponding of water near the joint.	Regular cleaning of the joint and pavement. Replacement of joint with similar type or different appropriate type.

Defect	Description	Image	Possible Causes	Remedy
3. Missing parts	This occurs when some bridge members are lost due to vandalism or failure of bridge members.		Vandalism. Tear and wear. Inadequate execution. Excessive vibrations. Wearing out due to heavy traffic.	Replacement of missing part with similar type or different appropriate type.
4. Loss of asphaltic joint sealant	This is when the provided joint sealant is lost/damaged.		Workmanship. Wearing out due to heavy traffic.	Replacement of the asphaltic joint sealant. Replace the joint with a different type.

Defect	Description	Image	Possible Causes	Remedy
5. Leaks	This is when water and other unwanted materials leaks through the joint to the elements below.		Wearing of the joint sealant/ drainage membrane. Workmanship. Vandalism.	Regular replacement of the joint sealant/ drainage membrane. Replace the joint with a different type that does not allow leakage to the elements below the joint.
6. Siltation	This is the accumulation of unwanted material on the provided gap that will hinder proper functioning of the joint.		Deposition of soil and other solid materials by the road users, surface water or wind.	Regular cleaning of the joint using water/air jet.

Table 2.16 Common defects on approach slab

Defect	Description	Image	Possible Causes	Remedy
1. Settlement	This is evidenced by an uneven transition between the roadway and the bridge deck.		Erosion of materials in the layers below the approach slab. Consolidation of underlying natural foundation soils. Compression of materials directly beneath the approach slab. Settlement of abutment.	Address the cause of the settlement then either replace the approach slab or strengthen it.
2. Cracks	Cracks develop in concrete when stresses in the concrete exceed its strength.		Overloading. Separate settlement and erosion. Inadequate design of approach slab.	Crack sealing. Slab jacking. Member replacement.

Defect	Description	Image	Possible Causes	Remedy
3. Potholes/holes	Potholes can occur in the pavement layers above the approach slabs.		Corrosion of rebars. Inadequate cover. Wheel traffic action.	Repair by patching. Provide an approach slab. Replace/strengthen the existing approach slab.

Table 2.17 Common defects on reinforcing members

Defect	Description	Image	Possible Causes	Remedy
1. Breakages	When subjected to excess loads the reinforcing members break.		Overloading. Inadequate design. Vandalism.	Replace with an adequate member. Strengthen member.
2. Corrosion	Corrosion leads to reduction in member capacity and is the primary cause of sectional loss in steel members.		Deterioration/lack of protective agent. Water leakages. Siltation.	Prepare surface, apply primer and protective paint. Repair the leaking joints/drainage systems. Repair leakages.

Defect	Description	Image	Possible Causes	Remedy
3. Cracks	Cracks may develop in reinforcing members as a result of shear stresses, flexural moments or fatigue usually occurring at points of high stress concentrations.		Stress. Inadequate member.	Replace with a new member. Strengthen member.
4. Deformation	Deformation results from accidental/impact loading on reinforcing members.		Overloading. Impact.	Replace with a new member. Axle load enforcement

Defect	Description	Image	Possible Causes	Remedy
5. Missing parts	This occurs when some bridge members are lost.		Workmanship. Vandalism. Failure of members. Adverse environmental conditions.	Replace the missing parts.
6. Delamination	This is the loss of bond between the reinforcing member and the main member.		Inadequate execution. Temperature fluctuations. Differential expansion and contraction of the reinforcing members and the main member.	Repair the bond. Remove and replace/return the reinforcing member.

Table 2.18 Common defects on girder end

Defect	Description	Image	Possible Causes	Remedy
1. Misalignment	The abnormal gap between the girder end and the backwall of an abutment may be caused by lateral movement of the abutment or inadequate allowance for the movement during construction.		Faulty bearings. Displacement of the abutments or piers. Workmanship.	Replace faulty bearings. Underpinning of foundation. Replacement of abutments/piers. Slab jacking. Cleaning the gap. Impact.
2. Accumulation of debris	These are debris deposits present at the girder end. The accumulated debris limit the movement thus may cause cracking or crushing of the girder.		Leaking joints. Poor drainage.	Regular cleaning of the girder ends. Repair the leaking joints/poor drainage.

Table 2.19 Common defects on anchorages

Defect	Description	Image	Possible Causes	Remedy
1. Breakages	This is the fracture of anchoring material.		Inadequate design. Overloading. Unplanned natural occurrences.	Replace the broken anchorage.
2. Corrosion	Corrosion leads to substantial reduction in member capacity and is the primary cause of sectional loss in steel members.		Worn out/lack of protective coating.	Prepare surface, apply primer and protective coating.

3. BRIDGE MAINTENANCE AND REPAIR

3.1 Introduction

This section addresses the bridge maintenance and repair approach and methods. It begins with Minor Maintenance followed by Major Maintenance.

The overall aim of bridge maintenance and repair interventions is based on the following principles;

- Preserve bridge infrastructure assets and increase durability and value for money.
- Improve overall safety of the users in the road network.
- Minimize likelihood of catastrophic failures.
- Increase the service life of bridge structures.

3.2 Selection of Repair Methods

Figures 3.1 to 3.5 show the recommended repair methods for defects on concrete and steel structures.

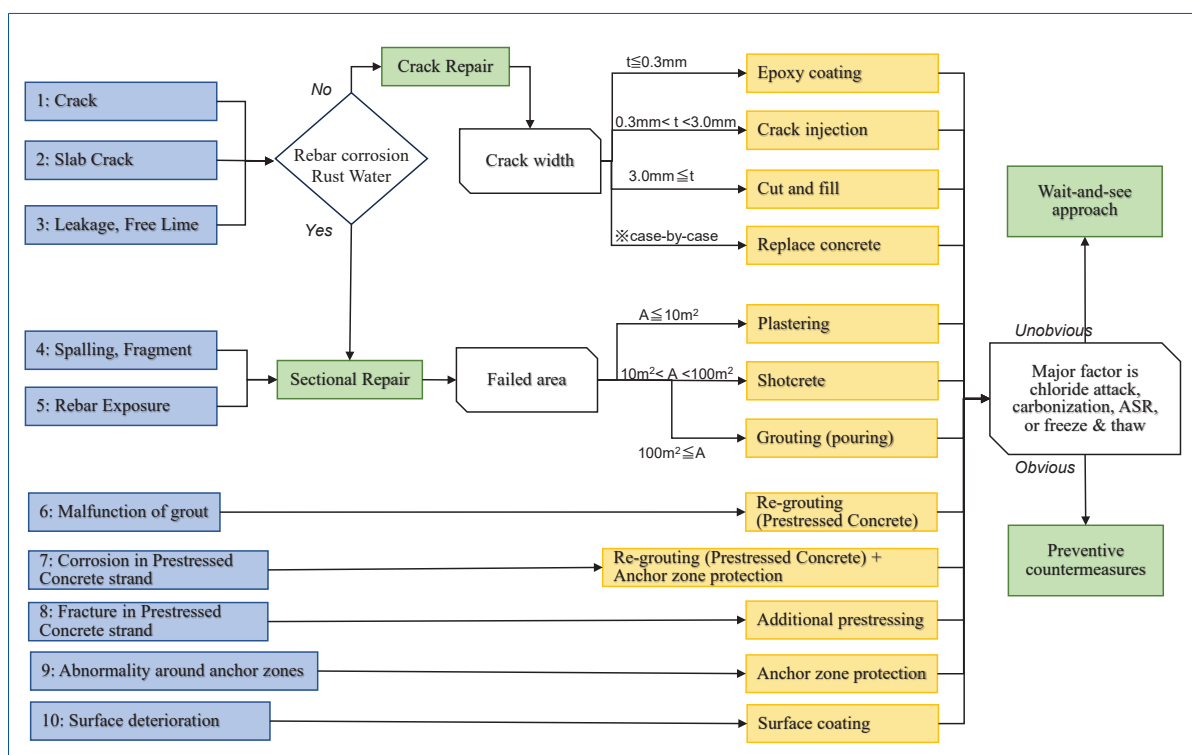


Figure 3.1 Selection of concrete repair methods

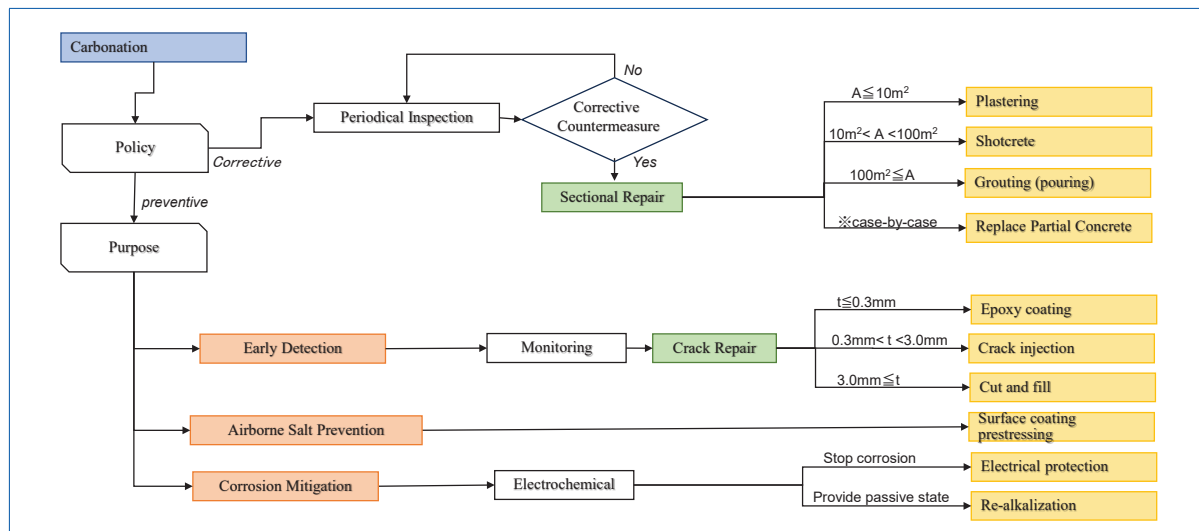


Figure 3.2 Selection of concrete repair methods for carbonation

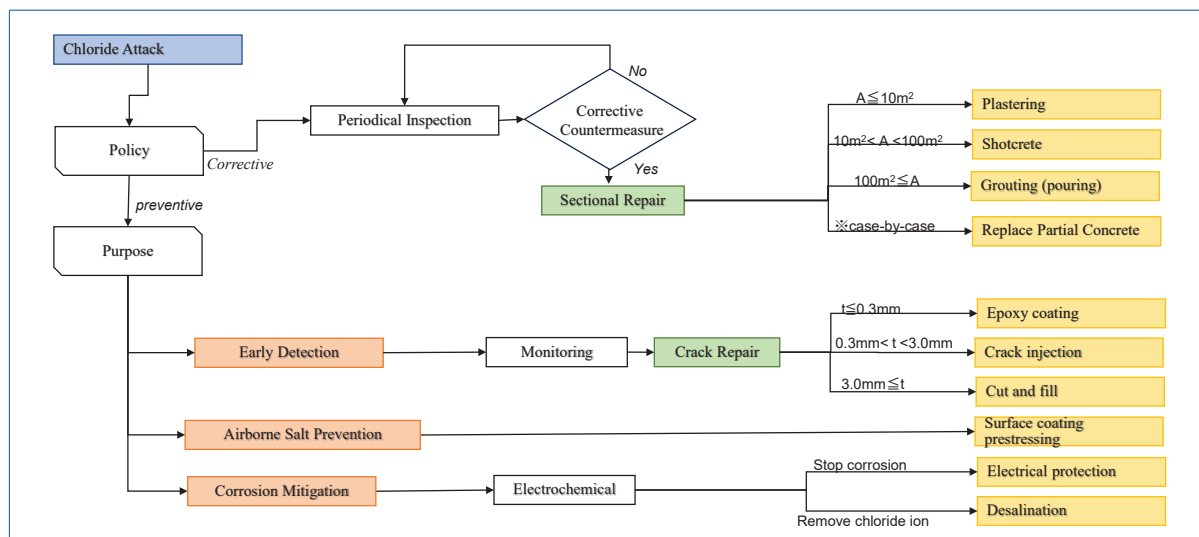


Figure 3.3 Selection of concrete repair methods for chloride attack

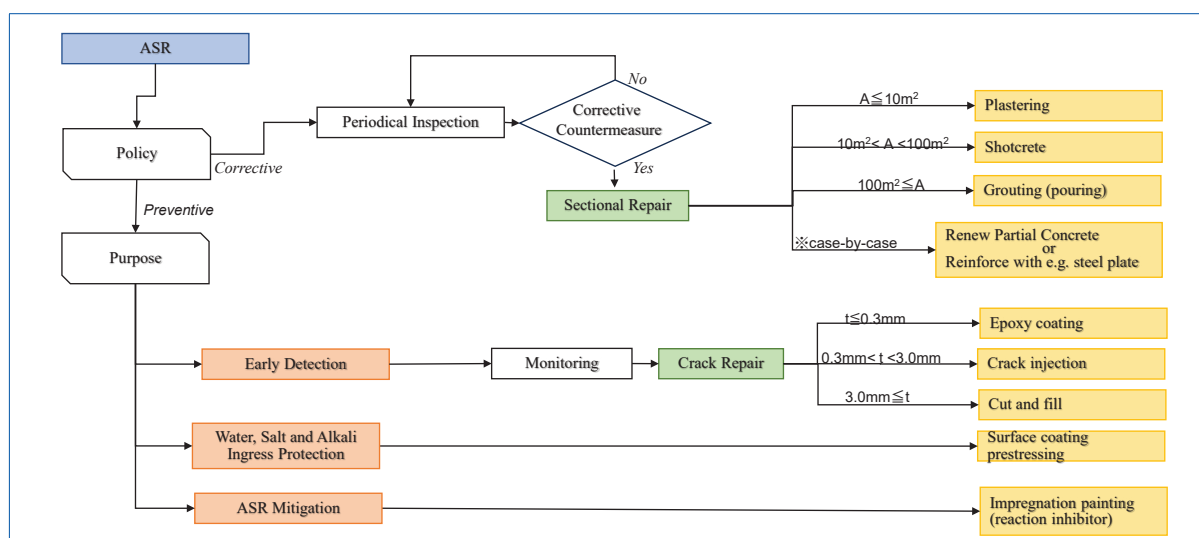


Figure 3.4 Selection of repair methods for concrete Alkali-Silica Reaction

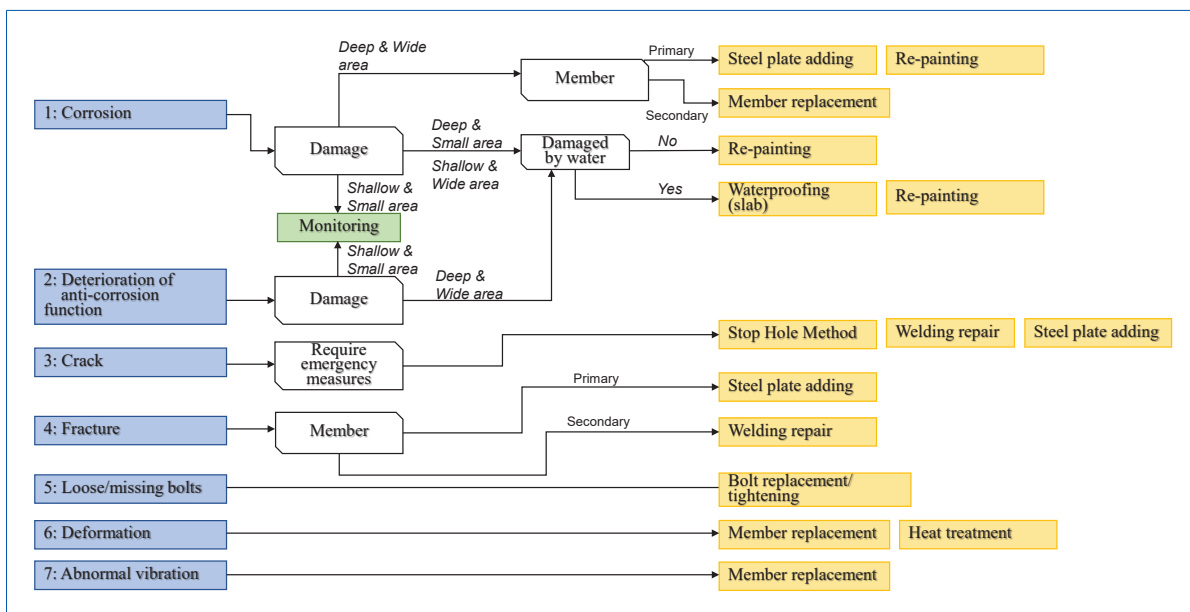


Figure 3.5 Selection of steel repair methods

3.3. Minor Maintenance and Repairs

These are interventions undertaken to prolong functionality of the bridge members.

3.3.1 Minor Maintenance and Repairs Method

Minor repair methods carried out on steel and concrete bridges are: cleaning, touch-up painting, epoxy coating on cracks, patching/plastering, removal and disposal of driftwoods/debris, partial replacement of stone masonry, and partial replacement of gabion wire mesh and stone.

The defects addressed in this section of the manual are listed in Table 3.1.

Table 3.1 Defects addressed in minor maintenance and repairs

Classification	Repair/Strengthening Method	Method	Defects Addressed
Minor Maintenance and Repairs	Maintenance	Cleaning	Siltation Clogging/Obstructions Vegetation Discoloration Accumulation of water
		Removal and disposal of driftwoods/debris	Clogging/Obstructions Vegetation
	Repair	Touch-up painting	Paint deterioration Corrosion
		Epoxy coating on cracks	Cracks

Classification	Repair/Strengthening Method	Method	Defects Addressed
	Repair	Patching/Plastering	Spalling with rebar exposure Spalling Sand streak Honeycombs Delamination Scaling Disintegration
		Partial replacement of stone masonry	Broken
		Partial replacement of gabion wire mesh and stone	Missing parts Corrosion

3.3.1.1 Cleaning

Definition

This involves the removal of debris by hand sweeping, shovel, high-pressure water/air or mechanical devices.

Cleaning of deck, bearings, drains and expansion joint is important before bridge inspection to detect any damage and deterioration of structures. The drainage must be cleaned regularly to prevent clogging of rainwater which may trigger the rusting of structural members.

Cleaning works should be performed on the bridge to prevent its deterioration. These works should include the removal of all accumulated foreign materials from the entire bridge such as its deck, sidewalk, kerb, trusses and its web members, lower flanges of beams or girders, expansion joints, bridge seat areas, wind bracing and drains. After cleaning, these areas should be kept free from further accumulation of sand, gravel, dirt, and other foreign materials.



Figure 3.6 Cleaning illustration

Scope of Works

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

i. Surface of steel plate

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

ii. Bridge deck slab

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

iii. Bridge substructure

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

Required Materials, Tools/Equipment and Personnel

i. Required materials

- Water
- Fuel

ii. Required tools/equipment

Cleaning equipment shall consist of hand tools, high pressure water equipment, water bowser, and water pumps with associated delivery hardware necessary to properly flush, clean, and remove all foreign materials from the bridge. Other types of cleaning equipment may also be used subject to the approval of the Engineer. Clean water is recommended. For tools and equipment, refer to Table 3.2.

Table 3.2 List of required tools and equipment

No.	Tools	Purpose
1	Hand/Mechanical shovel	Removing debris
2	Ladder/Scaffold/Inspection vehicle	Access to high and hard to reach areas
3	Hand/Mechanical broom	Removing debris
4	Water bowser, generator, water pump, high pressure water equipment	Supply of water for flushing out debris
5	Air blower/Compressor	Removing debris
6	Garbage bags	Carting away debris
7	PPE	Protection of workers

Other equipment such as inspection vehicle, access trucks or movable scaffolding

devices may be necessary to access the areas to be cleaned.

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. Cleaning the steel plate surface

The steel plate surface shall be cleaned by washing out debris, chlorides or other chemical deposits known to accelerate corrosion. Washing with high pressure water equipment to completely remove all toxic substances is carried out from top to bottom and from end to the centre of the steel girder.

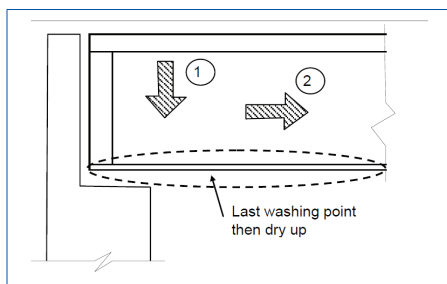


Figure 3.7 Sequence of cleaning girders

ii. Bridge deck cleaning

All foreign materials such as silt, dust, sand, rain water, and moss on concrete surfaces and at the gaps between girders shall also be completely removed manually and then washed using a high-pressure water equipment.

The following areas on the deck should also be carefully cleaned:

- Expansion joints
- Drainage ducts

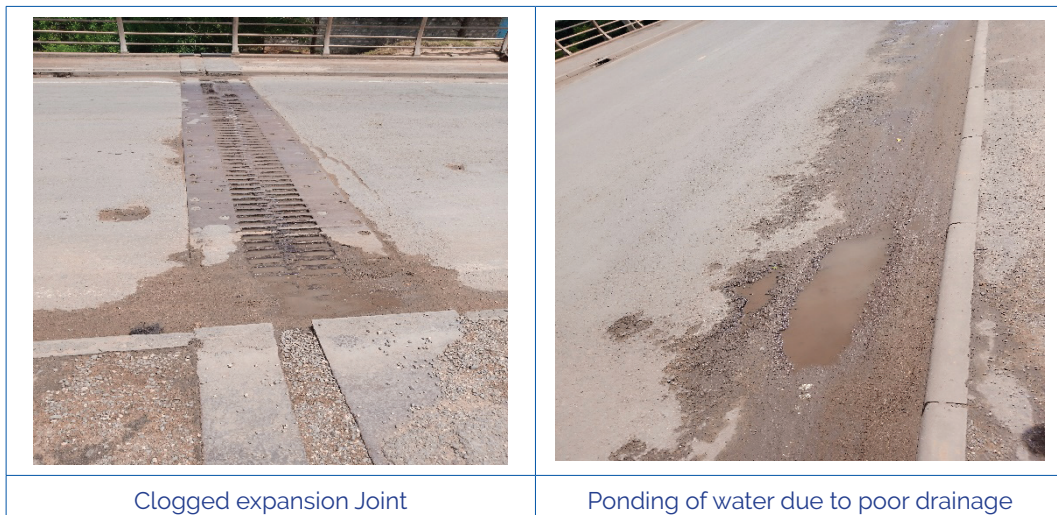


Figure 3.8 Bridge deck cleaning

iii. Cleaning of bridge substructure

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

iv. Inspection after cleaning

Visual inspection on all surfaces cleaned shall be supervised and approved by the Engineer. Other important measures include monitoring accumulation of the silt on bridge deck surfaces and accessories.

Monitoring and Evaluation

- Continuous cleaning,
- Weekly/Daily activity,
- Dust/litter source analysis.

Table 3.3 Monitoring and evaluation frequency for cleaning

Road Class	Structure Location		Traffic volume (Veh./day)		
	Urban	Rural	Above 10000	5000-10000	Below 5000
A	Weekly	Monthly	Weekly	Weekly	Weekly
B	Weekly	Monthly	Weekly	Weekly	Monthly
C	Monthly	Quarterly	Monthly	Monthly	Quarterly
D	Monthly	Annually	Monthly	Monthly	Annually
E	Monthly	Annually	Annually	Annually	Annually
R and U	Monthly	Annually	Annually	Annually	Annually

Measurements and Payment

Measurement shall be in square meters of surfaces cleaned and approved.

Payment shall be considered as full compensation for supplying all materials, labour, and equipment and for the performance of all works necessary for the flushing, washing, cleaning, removal and disposal of all foreign materials and debris, in accordance with the contract documents.

3.3.1.2 Touch-Up Painting

Definition

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

Touch-up painting is done to prevent corrosion. This work only covers painting of small (localized) areas where hand and power tools preparation is the only feasible method. Large areas, where sand blast cleaning can be justified, should be painted in accordance with the repainting procedure as described in major maintenance repairs.

Scope of Work

The method of application and the conditions under which paints are applied have a significant effect on the quality and durability of the coating. Standard methods used to apply paints to structural steelwork include application by brush, roller, conventional air spray and airless spray.

Touch-up painting should be partially applied to rusted steel plate as shown in Figure 3.9 and in Table 3.4.

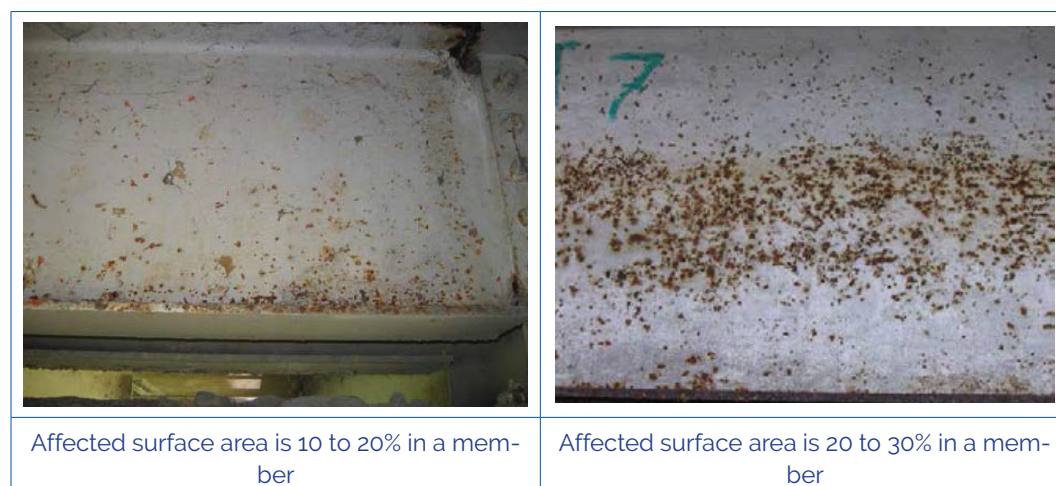


Figure 3.9 Rusted steel plate

Table 3.4 Preparation grades of the surface on corroded steel plate

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

Note: Affected surface beyond 30% are considered to be under major maintenance covered under section 3.3.2.1 of this manual.

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

Special anti-corrosion paint systems should be used for galvanised and heavily corroded steel surfaces. Ordinary selected patch paint such as aluminum painting is not suitable for galvanised surfaces.

Required materials, tools/equipment and personnel

i. Required materials

- Aluminium paint (locally available)
- Thinner
- Anti-corrosion paint

ii. Required equipment/tools

- Power disk grinder (portable type)/sand paper
- High pressure water equipment (8.0 MPa, 10.0 liters/min.)
- Portable generator (3.0 kVA)
- Paint roller (handy type) and brush
- Scaffolding or inspection vehicle

iii. Required personnel

Skilled personnel in paintworks trained by KIHBT and registered/accredited by NCA.

Preparation Works

- Provide traffic warning signs
- Identify and cordon work area
- Prepare diversion or lane management

Safety Considerations

- i. Provision of PPE's for the staff or labourers
- ii. Implementation of safety regulations as per the traffic management plans
- iii. Adhere to all environmental, occupational, safety and health regulations

Work sequence

i. Preparation of the steel surface

Depending on the severity of the corrosion on the members, the old coating film rust is removed with disc grinder, scraper or wire brush, partially revealing the steel surface. Sharp ridges and deep narrow grooves or pits shall be removed from the steel surface using power grinder. However, where depth of roughness is less than 0.5 mm adequate and durable paint system can be achieved without multiple coats of surface leveling paint. The maximum film thickness shall be as recommended by the manufacturer and approved by the Engineer.

ii. Touch-up painting

The paint components shall be mixed properly and applied in accordance with the manufacturer's instructions.

The paint shall be applied immediately after surface preparation, preferably within 4 hours on the same day.

Paint shall be applied using brush or roller to produce a uniform smooth coat without runs, streaks sags, wrinkles, or other defects.

The minimum total Dry Film Thickness (DFT) of the system should not be less than 125 micrometers (μm) (Aluminum paint) and 500 micrometers (special anti-corrosion paint).

The total DFT of special anti-corrosion paint shall be 500 μm (equivalent to 1.5 kg/m²) consisting of two layers of coating as follows:

- 1st layer: 250 μm
- 2nd layer: 250 μm

Visual inspection on surfaces repaired by touch-up painting shall be supervised and approved by the Engineer.

Monitoring and Evaluation

- Periodic inspection
- Corrosion source analysis
- Performance Test: Pigment or coating depth test, abrasion resistance, adhesion and resistance tests (water, chemical and fire) as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

This work will be measured for payment by the actual area in square meters (m²) of steel surfaces cleaned, painted and approved.

Payment shall be full compensation for provision of all materials, containers, equipment, tools, labor, services of the technical service advisor, and incidental work for the touch up painting of the structure. There will be no direct payment for the cost of storage or hauling of the paint and other materials to and from the bridge(s) to be painted, or for the containment, collection, and storage of hazardous or contaminated materials within the work areas. The cost thereof shall be deemed included in the price per square meter.

3.3.1.3 Epoxy Coating on Cracks

Definition

It is a protective measure where epoxy material is applied on concrete structures to seal vertical or overhead (sealing) cracks to prolong the bridge service life.

Scope of Works

This method is generally applied to cracks of widths less than 0.3 mm regardless if crack formation is structural or non-structural, and has no adverse effect on the structure.

In case the slab is leaking, waterproofing should be carried out first on top of the slab before sealing the cracks to avoid ponding of water in the slab.

The repair shall be undertaken as instructed by the Engineer.

Required materials, tools/equipment and personnel

- Required materials**
 - Epoxy sealant
- Required Equipment/Tools**
 - Brush or paint roller
- Required personnel**

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.
- A study on the cracks to determine the extents of width and number of cracks per square meter to be undertaken to inform intervention.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. **Preparation of Concrete Surface (cleaning of cracks)**
All cracks and surrounding surfaces shall be cleaned with water and oil-free compressed air.
- ii. **Application of Epoxy Sealant**
Ensure the area around the cracks is free from any protective coatings for improved adhesion.
Ensure that the cleaned arisings and coatings are carted away from the work site.
The surface preparation methods should comply with relevant cleaning standards as maybe applicable.
Apply approximately 50 mm width strips of epoxy sealant coating to concrete surfaces along the crack, as recommended by the manufacturer.
Monitor epoxy sealant for adequate setting and check bonding of coating.

Monitoring and Evaluation

Monitoring of crack width - The cracks coated with sealant shall be monitored by the Engineer, to determine if the cracks are progressing or not.

Measurements and Payments

Performance Test - Adhesion test, film thickness test and flexibility test.

Measurement shall be in square meters (m²) of the cracks where epoxy coating is applied, as determined and approved by the Engineer.

Payments shall include full compensation for supplying all labor, materials, tools, equipment, and incidental items. This also includes performing all the works involved in preparing the surfaces of existing concrete and application of epoxy coating, as specified on plans and specifications, and as directed by the Engineer.

3.2.1.4 Plastering

Definition

This is a method used to repair concrete surfaces that have been damaged by spalling or delamination.

Scope of Works

This repair method requires none or minimum formwork and it is generally applied using a trowel. The repairs are done to deck slab, superstructure and the substructure of the bridge.

Patching/ plastering is limited to a maximum thickness of 50mm depth.

This work involves patching concrete sections that have spalled or delaminated.

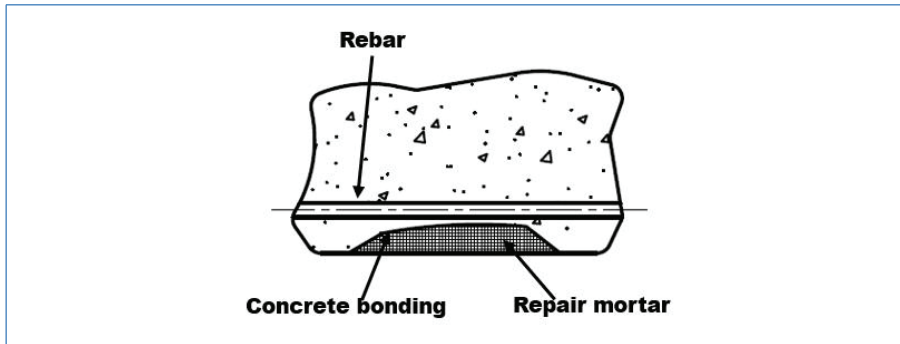


Figure 3.10 Plastering illustration

Required Materials, Tools/Equipment & Personnel

i. Required materials

- Portland cement mortar - Pre bagged (pre-packed) materials by supplier, In case of Portland cement, mix design with admixtures (chemicals) shall be shown.
- Ordinary Portland Cement
- Fine aggregate
- Polymer Cement - (PCM Powder, PCM Emulsion)
- Concrete nails
- Bonding agent to concrete (epoxy Bonding)
- Clean water

ii. Required tools/equipment

- Chisel
- Portable generator
- Wire brush
- Small hammer
- Mortar mix bucket
- Safety goggles
- Trowel
- Scaffolding or inspection vehicle

iii. Required personnel

- Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.5 Cleaning of concrete surfaces

i. Removal of defective concrete.	
All unsound, defective and contaminated concrete should be removed and the edges prepared. If sectional loss (that require additional rebars) caused by corrosion is observed, then the removal of damaged concrete should be extended to the length needed to bond the additional rebars.	
ii. Cleaning of surfaces of concrete and rebar	
Loose particles should be removed to the satisfaction of the Engineer using high pressure water, sandblasting or vacuum cleaner. The concrete surface to be bonded must be free from dirt, oil, grease or asphalt. Rust must be removed before placing the new concrete. If deterioration is due to chloride contamination or if the reinforcement is covered with loose corroded elements and has developed pits, use water abrasive blasting until all the rust is removed.	
iii. Applying epoxy bonding coats to concrete and rebar	
Epoxy bonding coats are applied to clean and dry concrete surfaces in order to bond firmly. Specially formulated resins are also available for damp surfaces. Apply the epoxy bonding coat to steel bars with a brush working vigorously to ensure that they are evenly covered.	
iv. Mix design	
The Engineer to undertake the mix design informed by the available materials, nature of damage, curing time and any additives that may be required.	
Check the mix proportions, workability, consistency during placing and pockets or honeycombs after casting.	

v. Placing mortar The mortar should be placed in layers of a thickness of about 20 mm. Compact each layer thoroughly over the entire surface using a wooden trowel. Generally, there should be no time delays between the placing and compacting of layers. The patching to the surrounding concrete is performed using a form material, and then hammered using a mallet, wood floating or steel trowel.	
vi. Curing All types of cement repairs need curing for a minimum of 7 days to gain strength and to minimize drying shrinkage.	

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Measurements and Payments

Measurement shall be square meters (m^2) for depth less than 50mm calculated as the area instructed by the Engineer.

Payment shall include full compensation for the removal of deteriorated concrete, surface cleaning and preparation, furnishing and placing of all materials, labour, equipment, tools, as well as construction and removal of formworks and other temporary works necessary to complete the patching works.

3.2.1.5 Removal and Disposal of Obstructions from Structure Openings

Definition

This work involves the removal of driftwoods/debris around inlets and outlets of structures and disposal to a designated area.



Figure 3.11 Obstructions on structure openings

Scope of Works

Driftwoods and debris lodged on the inlets and outlets of structures should be removed at an early stage of routine maintenance otherwise it will become more difficult to dislodge thus increasing the risk of bridge or slope failure. Removal and disposal of driftwoods and debris shall be carried out once a year, or after an occurrence of floods when necessary.

Required Materials, Tools/Equipment and Personnel

- i. Required materials
 - Fuel
- ii. Required equipment/tools
 - Power saw
 - Scaffoldings/Inspection vehicle
 - Axe/Panga
 - Dump truck
 - Back hoe
 - Ropes
 - Tractor
- iii. Required personnel
 - Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

1. **Access** — Provide adequate access to the affected areas such as inlets and outlets.
2. **Cutting into pieces** — Large driftwoods shall be cut into small pieces and disposed to a designated area approved by the Engineer.
3. **Inspection** — The Engineer shall carry out visual inspection to ensure that the structure is in a free flowing condition.

Inspection vehicle with scaffolding device can be utilized also for the works.

Monitoring and Evaluation

- Cause analysis.
- Monitor the catchment area.

Measurements and Payment

Measurement shall be lump sum for sites described and approved by the Engineer.

Payment shall include full compensation for cutting, loading, hauling, disposing of driftwoods and cleaning the right of way at each location noted on the plans and for all labour, equipment, tools, and other necessary accessories to complete the work.

3.2.1.6 Partial Replacement of Stone Masonry

Definition

This involves restoration of the missing stones from masonry slope protection.



Figure 3.12 Partial replacement of masonry slope protection

Scope of Works

It involves replacement of the damaged/missing masonry slope protection with stone during the early stage of routine maintenance; otherwise, it will become more difficult to repair the damages, increasing the risk of slope failure. The stone patching shall be carried out when necessary.

Required Materials, Tools/Equipment and Personnel

- i. **Required materials**
 - Stones
 - Gravel
 - Cement
 - Fine aggregates

Water
Hoop iron
PVC pipes
Damp Proof Course

ii. Required tools/equipment

Trowel
Wheelbarrow
Dump truck
Spades
Mortar mixer
Water bowser

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Before commencement of this work, a method statement should be approved by the Engineer.

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

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

The damaged area is replaced by installation of new stone masonry according to alignment and dimensions as shown in the drawings or as directed by the Engineer.

Check the level and slope alignment, consistency, bonding and shrinkage.

Monitoring and Evaluation

- Cause analysis.
- Monitoring of repaired section by the Engineer.

- Performance Test – Compressive test on samples as per the Standard Specifications for Bridge Repair in Kenya and any other applicable standard..

Measurements and Payment

Measurement shall be based on square meters (m²).

Payment shall include full compensation for provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.2.1.7 Partial Replacement of Gabion Wire Mesh and Stone

Definition

This is the restoration of damaged section of the gabion wire mesh and/or missing stones.

The gabion mattress protects abutment and pier behind them from the erosive action of water flow. Gabion wire can either be destroyed by strong river flow during rainy season or vandalism.



Figure 3.13 Partial replacement of gabion wire mesh and stone

Scope of Works

Replacement of broken gabion wires should be done at an early stage of routine maintenance otherwise it will be more difficult to repair the damage and the risk of gabion failure will have increased.

Required Materials, Tools/Equipment and Personnel

- i. **Required materials**
 - Stones as per the specifications
 - Wire mesh
 - Binding wire
 - Cement
 - Fine aggregates
 - Water
- ii. **Required tools/equipment**
 - Pliers
 - Hack saw
 - Wheelbarrow
 - Dump truck
 - Spades
 - Mortar mixer
 - Water bowser

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. Remove the damaged wire mesh section from the gabion mattress
- ii. Replace the damaged section of the wire mesh as directed by the Engineer.
- iii. Fill the gabion mattress with additional stones if required. The stones should have minimum size 150mm and maximum size 300mm
- iv. The sides shall be packed first using large pieces and the internal using smaller pieces.
- v. The joints of the gabion boxes shall stitched together with binding wire as directed by the Engineer.
- vi. Exposed surfaces of the gabion boxes maybe grouted with cement mortar.
- vii. Curing of the grouted surfaces shall be monitored as directed by the Engineer.

Monitoring and Evaluation

- Cause analysis.
- Monitoring of repaired section by the Engineer.

Measurements and Payment

Measurement shall be based on square meters (m²) for the gabion mesh and cubic metres (m³) for the stones.

Payment shall include full compensation for provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.3 Major Repairs

These are substantial and extensive interventions aimed at restoring structural integrity, safety and functionality to an existing bridge that has undergone significant damage, deterioration or aging.

3.3.1 Major Repair Methods in Concrete Bridges

Major repair methods in concrete bridges are: epoxy injection, patching/sectional repair, caulking, carbon fibre sheet bonding to deck slab, steel plate bonding, partial deck slab replacement, water proofing on deck slab, fast setting concrete for continued deck slab, protective mortar, protective coating, recasting concrete / grout, carbon fibre sheet/ plate bonding to concrete girder, and jacketing with concrete.

The principles outlined and defined in EN 1504, Part 9, shall guide the Engineer to correctly repair and protect all of the potential damage that can occur in reinforced concrete structures.

The defects addressed in this section of the manual are listed in Table 3.6.

Table 3.6 Defects addressed in major repair to concrete bridges

Classification	Repair/Strengthening Method	Method	Defects Addressed
Major Repairs	Repair	Epoxy Injection	Crack Leakage Leaching and staining
	Repair	Patching/ Sectional repair	Spalling with rebar exposure Spalling Sand streak Honeycombs Delamination Scaling Disintegration Abrasion Cavity
	Repair	Caulking	Crack
	Strengthening	Carbon fibre sheet bonding to deck slab	Excessive deformation, deflection/vibrations Fatigue
	Strengthening	Steel plate bonding	Excessive deformation, deflection/vibrations Fatigue
	Repair	Partial deck slab replacement	Excessive deformation, deflection/vibrations Fatigue

Classification	Repair/Strengthening Method	Method	Defects Addressed
Major Repairs	Preventive	Water proofing on deck slab	Crack Efflorescence Moisture leaks
	Repair	Fast setting concrete for continued deck slab	Spalling with rebar exposure Spalling Abrasion
	Preventive	Protective mortar	Chemical attack Carbonation Salt attack Alkali Silica Reaction Surface bubble Sand streak Cold joint Corrosion
	Preventive	Protective coating	Chemical attack Carbonation Salt attack Alkali Silica Reaction Surface bubble Sand streak Cold joint Corrosion
	Repair	Recasting concrete / grout	Spalling with rebar exposure Spalling
	Strengthening	Carbon fibre sheet/plate bonding to concrete girder	Excessive deformation, deflection/vibrations Fatigue
	Strengthening	Jacketing with concrete	Buckling
	Repair	Replacement of member (section 3.4)	Excessive deformation, deflection/vibrations Buckling

3.3.1.1 Epoxy Injection

Definition

This is an economical method of repairing non-moving cracks in concrete structures and is capable of restoring the concrete to its pre-cracked strength.

Scope of Works

The works include preparation of concrete surface, insertion of pipe fittings, bonding with adhesion, injection of epoxy, curing and conducting performance test.

Required Materials, Tools/Equipment & Personnel

- i. Required materials
 - Epoxy Resin
 - Sealant
 - Injection Port
- ii. Required tools/equipment
 - a. *For surface preparation*
 - Power disc grinder
 - Wire brush/Air gun
 - b. *For fixing repair method*
 - Hand mixer
 - c. *For setting repair material*
 - Epoxy injection pump/gun
 - d. *Finishing*
 - Power disc grinder
 - Portable generator
- iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Epoxy may be dangerous when it comes in contact with the skin and if breathed in for a long period.

In application of the Epoxy, the following precautionary measures should be taken:

1. Wear long sleeved tops and long trousers.
2. Wear shoes and socks since epoxy will drip onto the feet.
3. Wear disposable vinyl gloves.

4. Tape over the joint between the gloves and the sleeve if necessary.
5. Take care not to rub the wrist with the dirty fingers of the other hand when removing gloves.
6. Wash any splashes with warm soapy water as soon as possible.
7. Never use solvents.

When sanding, the following precautionary measures should be taken:

1. Never use solvents.
2. Wear long sleeved tops and long trousers and consider wearing coveralls.
3. Wear shoes and socks.
4. Wear a dust mask.
5. Wear a hood or hat and scarf.
6. Wear gloves.
7. Reduce the area of exposed skin to a minimum.
8. Wash dust off skin and hair as soon as convenient.
9. Wash clothing after each exposure.

Maintaining a Clean Work Environment

- Maintain a clean workshop to avoid incidental contact with the epoxy resin. If you have epoxy residue on your gloves, don't touch door handles, light switches, or epoxy containers because you'll probably touch them again when you're not wearing gloves.
- Clean up epoxy spills with a scraper, collecting as much material as possible. Follow up with paper towels.
- Contain large spills with sand, clay, or other inert, absorbent material. DO NOT use sawdust or other fine cellulose materials to absorb hardeners. You may reclaim uncontaminated resin or hardener for use.
- Clean up resin or mix epoxy with acetone, lacquer thinner, or alcohol. Follow all safety warnings on solvent containers.
- DO NOT dispose of hardeners in the trash containing sawdust or other fine cellulose materials – they can spontaneously combust.
- Clean hardener residue with warm, soapy water.
- Pots of curing epoxy can get hot enough to emit hazardous fumes and ignite combustible materials nearby. Place pots of mixed epoxy in a safe and ventilated area, away from works and combustible materials.
- Dispose of the solid epoxy mass only after it has completely cured and cooled.

Work Sequence

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

Table 3.7 Epoxy injection work sequence

i. Cleaning of cracks All loose debris and contaminants (oil, grease, etc.) shall be marked out and removed from the cracks using high-pressure water, or special and effective solvent. Remove residual water or solvent in the crack with filtered (dust and oil free) compressed air and allow adequate time for drying.	
ii. Installation of pipe fitting The pipe fittings shall be fixed at intervals along the length of each crack. The spacing of the pipes varies between 150mm to 500 mm, considering the width and depth of crack. The first and last pipe fitting are set at or near the bottom and top, respectively.	
iii. Crack sealing Using a 5 cm wide strap, epoxy sealant is applied on the area around the pipe fitting and cracks, allowing it to harden.	
iv. Fitting of injector Connect the injector terminal to the pipe fittings.	

v. Injection of Epoxy

Epoxy shall be injected using air-activated epoxy injection guns. 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.

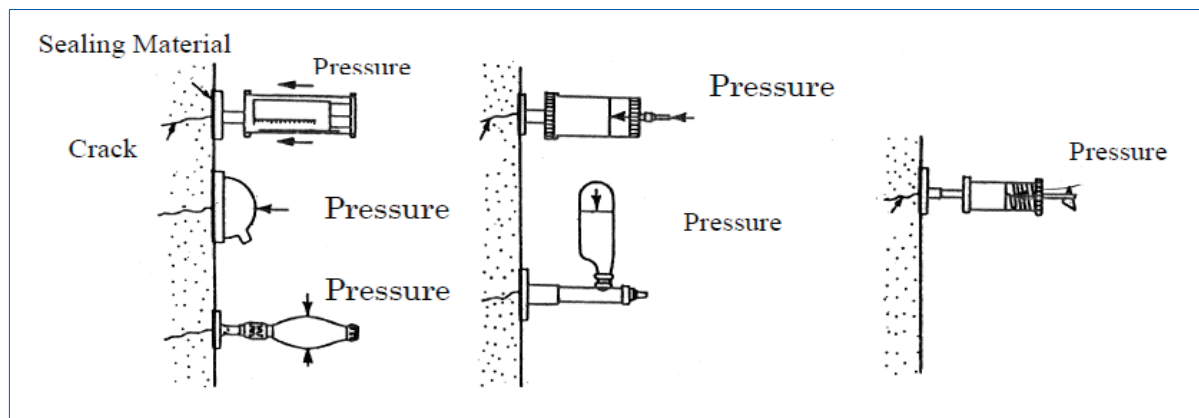


Figure 3.14 Crack injection method

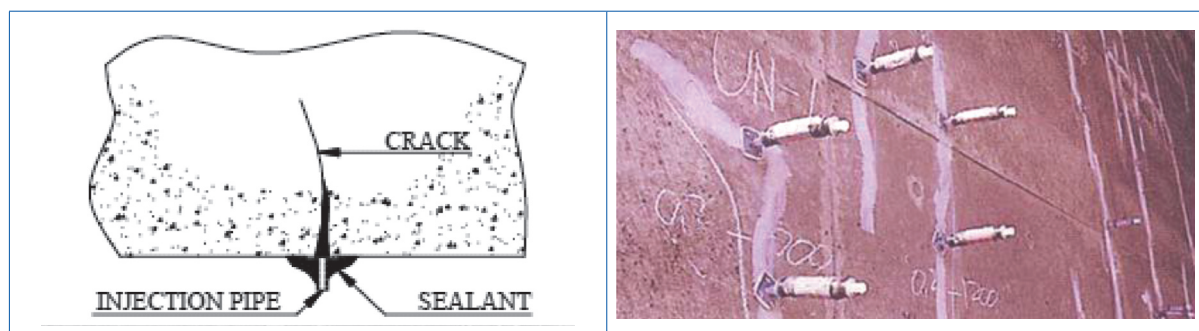


Figure 3.15 Crack injection penetration

vi. Curing of injected material

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



vii. Performance test

Low frequency pulse velocity ultrasonic inspection will determine if the epoxy resin has penetrated the full depth of the crack. If incomplete penetration is revealed by inspection, such conditions shall be reworked.

In addition, adhesion test shall be done as per the specification.

Monitoring & Evaluation

- Monitoring of repaired section by the Engineer.

Measurement and Payment

Measurement shall be in linear metre (m).

Payment shall include full compensation for the removal of deteriorated concrete, surface cleaning and preparation, furnishing and placing of all materials, labour, equipment, tools, as well as construction and removal of formworks and other temporary works necessary to complete the epoxy injection.

3.3.1.2 Patching

Definition

Patching is the restoration of small areas where sound concrete is damaged by spalling, scaling, honeycombing or impact.

In this repair method the depth of the damaged concrete exceeds 50mm depth with exposure of rebars.

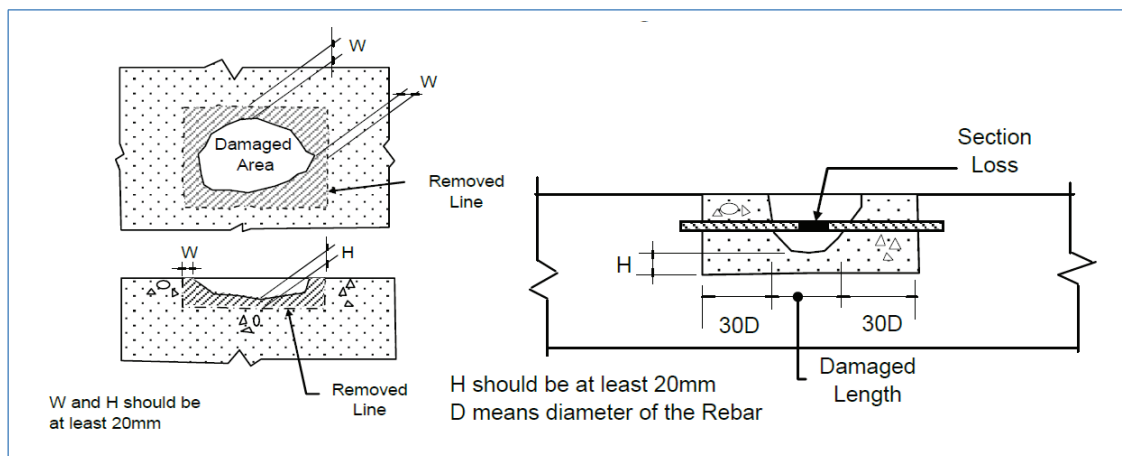


Figure 3.16 Limits of removal of damaged concrete

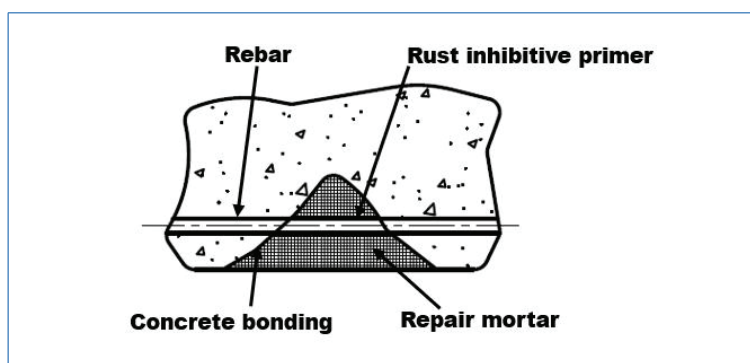


Figure 3.17 Illustration of patching

Scope of Works

This method of repair requires minimal or no form work. The patch thickness is limited to a maximum depth of 75 mm.

Depending on the location and extent of damage, patching may be done using either Portland cement mortars or polymer cement mortar.

Required materials, tools/equipment and personnel

i. Required material

Portland Cement Mortar	Polymer Cement Mortar (PCM)
- Pre-mixed and pre-bagged Portland cement mortar - Water - Concrete nail - Bonding agent to concrete (Epoxy Bonding)	- PCM powder - PCM Emulsion - Concrete Nail - Bonding Agent to Concrete (Epoxy Bonding)

ii. Required equipment/tools

Chisel
 Portable generator
 Wire brush
 Small hammer
 Mortar mixer
 Mortar mix bucket
 Safety goggles
 Trowel
 Scaffolding or Inspection vehicle

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

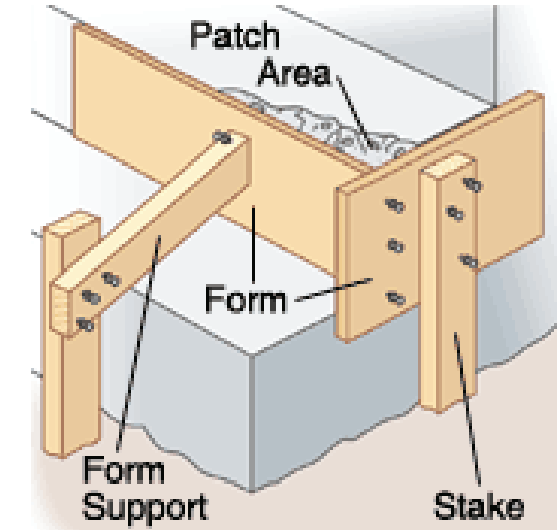
- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- Provision of PPE's for the staff or labourers,
- Implementation of safety regulations as per the traffic management plans,
- Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.8 Patching work sequence

i. Remove damaged concrete Using a small sledge hammer and chisel, remove all damaged concrete at corner edges of area to be repaired then use a wire brush to remove the loose debris.	
ii. Formwork installation If necessary, provide formwork around the damaged concrete to straighten the edges of the damaged section.	
iii. Application of bonding agent Bonding agent is applied to the damaged area in order for the patch material to adhere. Concrete nails/bids can also be set to reinforce the repair. If the rebar is exposed, anticorrosion agent coating on the bar surface should be applied prior to patching.	

iv. Placing cement mortar Use a trowel to spread fresh mortar over the area, covering the concrete nails driven halfway in the old concrete. Smoothen and level the mortar with a trowel. It should be noted that polymer cement mortar is suitable for both vertical and horizontal surface applications, with a thin coating of up to 15 mm. As may be required, it can be smoothed using a trowel.	Horizontal finish
	
	Vertical finish 
v. Curing Curing with water shall be done three times a day for a minimum of 7 days.	

Monitoring and Evaluation

Monitoring of patched section by the Engineer.

Performance Test - Bonding test and shrinkage test as per the Standard Specifications for Bridge Repair in Kenya and any other applicable standard.

Measurements and Payments

Measurement shall be square meters (m^2) for depth less than 50mm calculated as the area instructed by the Engineer or shall be measured by the cubic meters (m^3) for depth beyond 50mm calculated as the volume, or as instructed by the Engineer.

Payment shall include full compensation for the removal of deteriorated concrete, surface cleaning and preparation, furnishing and placing of all materials, labour, equipment, tools, as well as construction and removal of formworks and other temporary works necessary to complete the patching works.

3.3.1.3 Caulking

Definition

This method entails repairing of active cracks as movement joint with flexible sealants.

Scope of Work

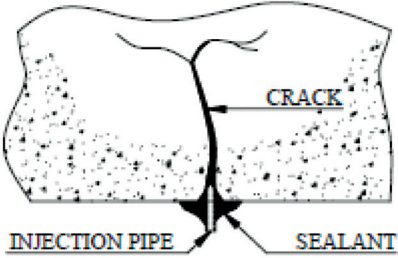
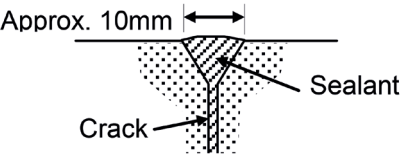
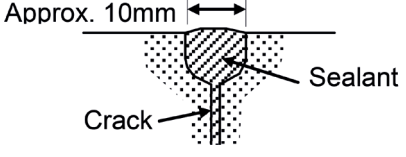
This involves application of sealant in a wide recess area cut along the crack. The dimension of the recess (width and depth) depends on the total crack movement and the cyclic movement capability of the joint sealant used. For selection of sealant material, crack movement should be calculated taking into account the applied loads, shrinkage and temperature variations.	
 (V-Type)	 (U-Type)

Figure 3.18 Types of caulking

Required Materials, Tools/Equipment & Personnel

- i. Required materials
 - Epoxy grout
 - Sealant
 - Injection pipe
- ii. Required equipment and tools
 - Grout Injection Pump or Caulking Gun
 - Power Disc Grinder/Cutter
 - Portable Generator
 - Brush
 - Set of Injection Tools
 - Ladder/hydraulic lift
- iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.9 Caulking work sequence

i. Cleaning of cracks All loose debris and contaminants should be removed from the crack using high-pressure water jet or special and effective solvent. The water and solvent should then be removed with the compressed air and allow adequate time for drying.	
ii. Preparation for caulking A V-groove or a U-groove of approximately 10mm in width and depth is prepared at the surface along the crack using a power disc grinder/cutter. The groove shall then be partially sealed with sealant.	
iii. Drilling of holes and fixing of injection pipes Portholes 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 sealed with sealant.	

iv. Injecting the Epoxy Grout

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

For horizontal cracks, the injection shall be carried out progressively from one end to the other.



v. 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 fibre sheet will be applied, the portions with sealant and tip of cut pipe should be grinded to form a smooth surface.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Adhesion test, penetration test and consistency test as per the Standard Specifications for Bridge Repair in Kenya and any other applicable standard.

Measurements and Payments

Measurement shall be in linear meters (m).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for caulking repair as detailed in plans and specifications.

3.3.1.4 Carbon Fibre Sheet Bonding to Deck Slab

Definition

This is a composite where a polymer matrix is reinforced with many relatively thin and long fibres. The carbon fibre sheet is used to enhance the load bearing capacity of the concrete deck slab and extend its service life.

Scope of Works

The works shall consist of furnishing and installing two types of arrangement of Carbon Fibre Sheets for concrete strengthening systems in accordance with the plans and specifications. The systems shall be designed to strengthen and stiffen concrete bridge deck slab and tested by the Engineer to verify performance.

In case the slab is leaking, waterproofing should be carried out first on top of the slab before strengthening the deck slab with CFS.

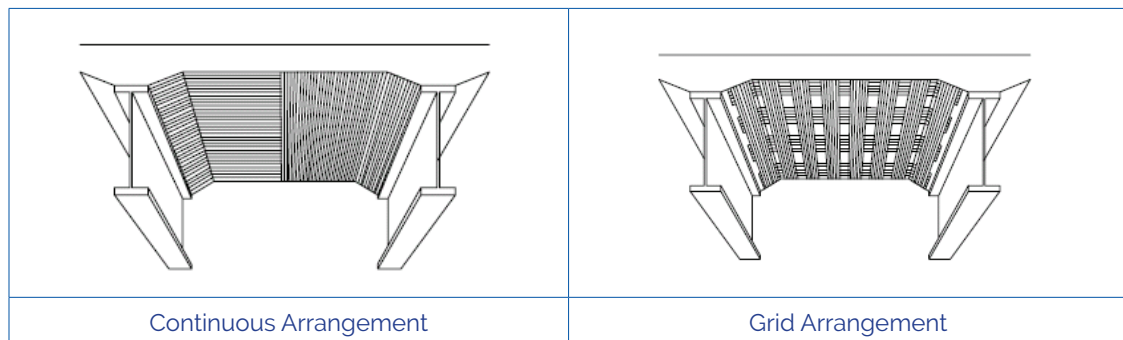


Figure 3.19 Arrangement types of carbon fibre sheet

Required Materials, Tools/Equipment and Personnel

- i. Required materials
 - Carbon fibre products
 - CFS (recommended strap type)
 - Epoxy materials
 - Epoxy primer
 - Epoxy putty
 - Epoxy resin adhesive
- ii. Required equipment
 - Abrasive Sandblaster
 - Air Compressor
 - Disc Grinder
 - Portable Generator
 - Paint Roller/Brush
- iii. Required personnel
 - Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.10 Carbon fibre sheet bonding to deck slab

i. Preparation of concrete surface	
The concrete surface is cleaned and smoothed using a disc grinder or abrasive sandblasting.	
ii. Application of primer	
The concrete surface is then coated with a primer resin to improve its bonding with the CFS.	
iii. Adjustment of unevenness with putty	
Any concave, pores, gaps on the concrete surface must be smoothed using epoxy putty.	
iv. Application of epoxy resin for undercoat	
When the epoxy putty becomes tack-free, epoxy resin is applied to the concrete, acting as adhesive to bond the CFS. The moulded composite is achieved as the resin permeates into the CFS.	

v. Installation of longitudinal layer CFS

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

Press the carbon fibre sheet by using plastic roller starting from the centre toward the edge.



vi. Installation of transversal layer CFS

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

Press the carbon fibre sheet by using plastic roller starting from the centre toward the edge.



vii. Squeezing out of entrapped air

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



viii. Surface protection

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

Alternatively, for sake of aesthetics and durability visible surfaces may be painted.



Monitoring and Evaluation

- Performance test – Carry out tensile test, shear test and adhesive tests.
- Frequency of tests – Tests can be done one year after installation of the additional plate and 5 years subsequently during the detailed inspection.
- Monitoring of repaired section by the Engineer.

Measurements and Payment

Measurement shall be in square metres (m²).

Payment shall be full compensation for provision for all materials, equipment, supervision, related services necessary for strengthening the concrete as detailed in plans and specifications.

3.3.1.5 Steel Plate Bonding

Definition

The technique of bonding steel plates to concrete deck slab/girder using epoxy adhesives on bridges to enhance their load carrying capacity.

Scope of Works

Steel plate is bonded with epoxy resin at the bottom or side face of existing girders. Bonded steel plate provides the same effect as that for installing additional rebar to existing girder. This does not require restriction to traffic. However, in case where the deterioration of the concrete surface is too severe, other measures to improve the quality may be considered.

The steel plate bonding for deck slab has two types, namely, wide plate and narrow plate. Wide plates are used for strengthening the slab in both the main reinforcing bar and distribution bar directions. Narrow plates are used for strengthening the slab in one direction only. The bonding of steel for deck slab is achieved using either the **injection method** or **pressure attachment method**.

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

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

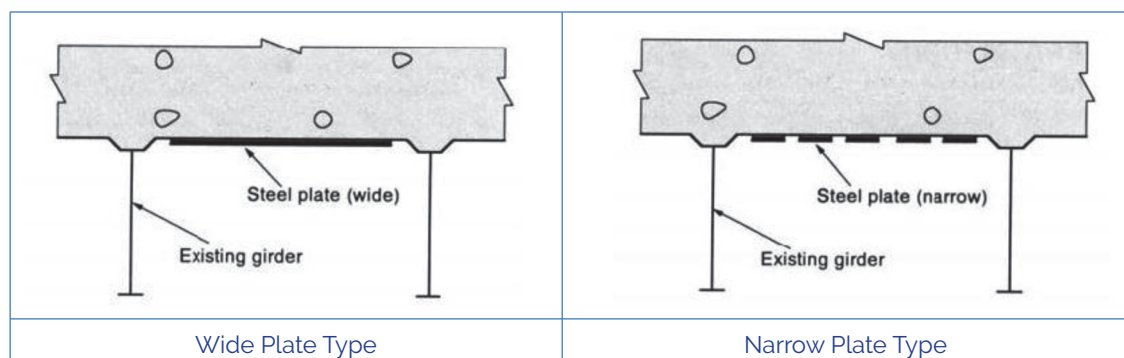


Figure 3.20 Types of steel plate bonding

Required Materials, Tools/Equipment and Personnel

i. Required materials

Injection method

- Steel plate
- Primer (epoxy base)
- Epoxy resin adhesive for injection
- Epoxy sealant
- Anchor bolts

Pressure attaching method

- Steel plate
- Primer (epoxy base)
- Epoxy resin adhesive
- Epoxy sealant
- Anchor bolts
- Wood and angle for fitting

ii. Required tools/equipment

Injection method

- Disc grinder
- Welder
- Electric drill
- Epoxy injection pump with accessories
- Wire brush

Pressure attaching method

- Disc grinder
- Welder
- Electric drill
- Epoxy injection pump with accessories
- Wire brush

iii. Required personnel

- Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. Injection method

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

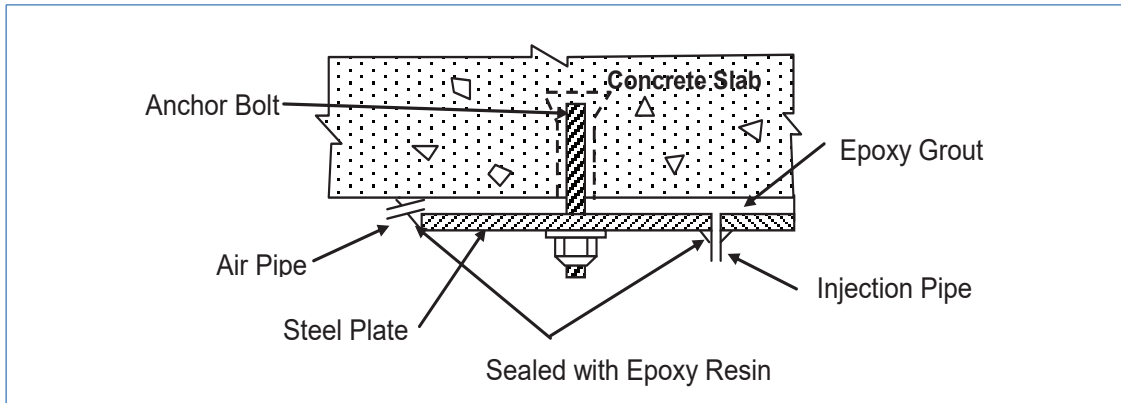
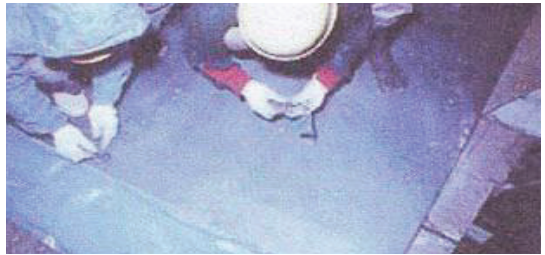
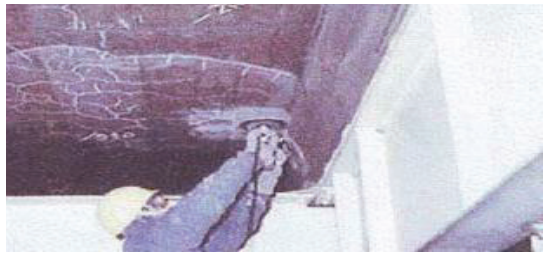


Figure 3.21 Detail of injection method sealing with epoxy adhesive

Table 3.11 Steel plate bonding (epoxy adhesive method)

i. Surface preparation	
The bottom surface of slab to be bonded with steel plate shall be cleaned the steel surface must also be completely free of any mill scale, rust, grease or other contaminants. Any surface irregularities shall be levelled using a disc grinder.	
The primer should be applied on the surface which is compatible with the adhesive.	
ii. Setting of steel plate on the slab	
Injection pipes are attached to the steel plate. Anchor bolts shall be provided to temporarily support steel plates (placed below the slab surface with an average gap of 5 mm) in the event that the deck slab settles. Joints between steel plates are welded at site.	

iii. Sealing of steel plate

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



iv. Injection of epoxy resin

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



v. Curing and painting

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



ii. Pressure attaching method

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

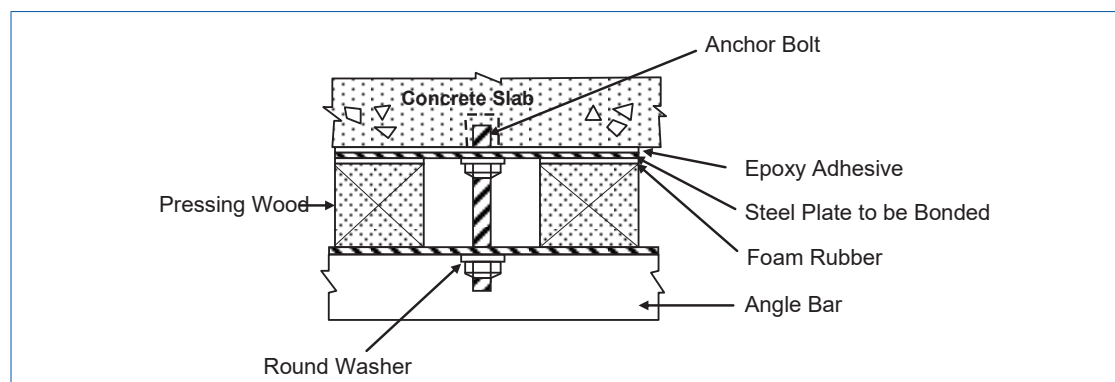


Figure 3.22 Detail of pressure attaching method by anchor bolts

Table 3.12 Steel plate bonding (pressure attaching method)

i. Surface preparation	
The bottom surface of slab/girder to be bonded with steel plate shall be cleaned the steel surface must also be completely free of any mill scale, rust, grease or other contaminants.	
Any surface irregularities shall be levelled using a disc grinder. The primer should be applied on the surface which is compatible with the adhesive.	
ii. Application of epoxy resin	
The adhesive shall be thicker along the center of the steel plate than at the sides. The use of plastic spacers maintains minimum adhesive thickness of 1-2 mm.	
iii. Pressure attachment of steel plate	
The epoxy resin adhesive is applied to the steel plate which is set at the required position of the deck slab/girder, and pressed using the anchor bolts wedging off with the temporary stiff wood and angular.	
iv. Curing and painting	
A suitable chamfer/fillet could also be formed in the adhesive around the edge of the plates and the concrete surfaces. Steel plates and all its components shall be adequately painted for corrosion protection.	

Monitoring and Evaluation

- Performance test – Carry out tensile test, shear test and adhesive tests.
- Frequency of tests – Tests can be done one year after installation of the additional plate and 5 years subsequently during the detailed inspection.
- Monitoring of repaired section by the Engineer.

Measurements and Payment

Measurement shall be in square metres (m²).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for strengthening the concrete as detailed in plans and specifications.

3.3.1.6 Partial Deck Slab Replacement

Definition

Partial deck slab replacement is carried out to replace a portion of concrete that has been severely damaged and spalled at either joints or at mid slab locations. If damaged portion is not removed, as shown in Figure 3.23, further deterioration is expected, which could impair the strength, stability and serviceability of the structure. The cause of such damage could be corrosion of reinforcement, fracturing, spalling, delamination, honeycomb or water leakage.

Scope of Works

Partial Deck Slab Replacement involves removal of the deteriorated concrete, cleaning up the underlying layer and reinforcement, setting up formwork and placement of new concrete.

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

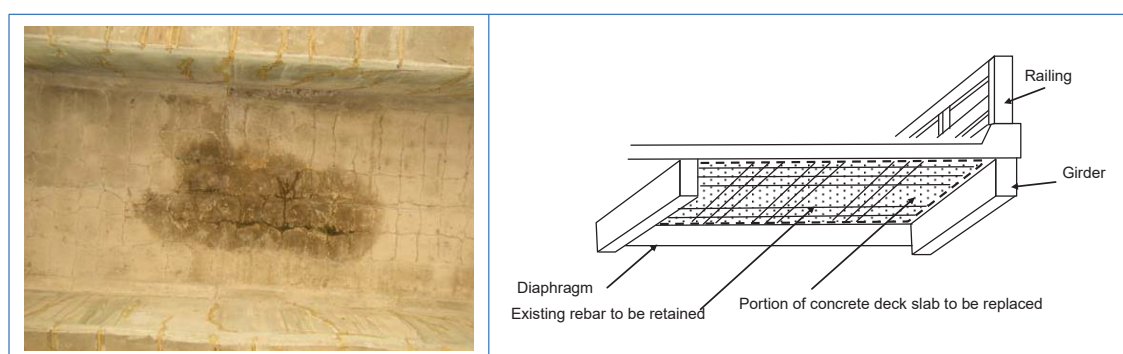


Figure 3.23 Severely damaged deck slab

Required Materials, Tools/Equipment and Personnel

i. Required materials

- Portland cement/fast setting mortar
- Aggregates
- Water
- Silica fume
- Rebar (Reinforcing bar, use minimum 16mm diameter)
- Epoxy resin (bonding coat to concrete)
- Anti-corrosion primer (bonding coat to rebar)

ii. Required tools/equipment

- Sawing equipment
- High pressure water equipment
- Handy concrete breaker or Jackhammer
- Handy power chisel
- Concrete mixer
- Vibrator
- Trowelling tools
- Air compressor
- Water bowser
- Scaffolding
- Formwork

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.13 Partial deck slab replacement

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

ii. Removal of deck slab concrete

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



iii. Preparation of old concrete and rebar

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



iv. Setting of formworks

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



v. Cutting of existing rebar and addition of new rebar

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

vi. Placing of concrete

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



vii. Curing and removal of formworks

Continuous water curing with wetted cotton mat is always preferable to slow down drying. Formworks for load bearing structural members shall remain in position for a minimum of 21 days.

Monitoring and Evaluation

- Performance test.
- Monitoring of repaired section by the Engineer.
- Shrinkage test, compressive strength test and concrete bonding test as per the Standard Specifications for Bridge Repair in Kenya and any other applicable standard.

Measurements and Payments

Measurement shall be based on cubic metres (m³) for replaced concrete on the deck, rebars will be measured in tonnes (Tons) and formwork shall be measured in square metres (m²).

Payment shall include full compensation for the replaced concrete on the deck, provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.3.1.7 Water Proofing on Deck Slab

Definition

Concrete water proofing is the application of an impervious layer on concrete. This layer prevents water from penetrating such that it remains relatively unaffected by water.

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

Scope of Works

The bridge deck waterproofing includes the sheet system and liquid (membrane) system. The liquid system involves a simple procedure similar to painting. In this repair manual, two types of liquid system are introduced, namely, rubberized membrane type and asphalt compound membrane type.

The rubberized type waterproof membrane mainly consists of chloroprene rubber. Meanwhile, the asphalt compound type consists of asphalt mixed with special rubber, which is melted in a mechanically agitated heating process.

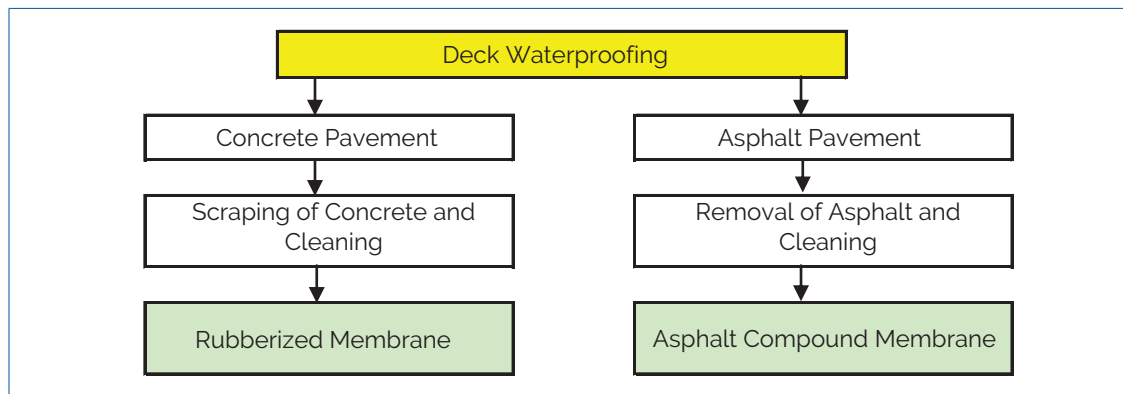


Figure 3.24 Flowchart for selection of waterproofing



Figure 3.25 Photo illustration of waterproofing

Required Materials, Tools/Equipment & Personnel

i. Required materials

Rubberized membrane

- Primer (1st layer)
- Rubberized membrane (2nd layer, 3rd layer and 4th layer)
- Tack coat (finish coat)

Asphalt compound membrane

- Primer
- Asphalt compound membrane
- Silica sand No.4

ii. Required tools/equipment

Rubberized membrane

- Paint roller

Asphalt compound membrane

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

iii. Required personnel

Skilled personnel works trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work sequence

(1) Rubberized membrane

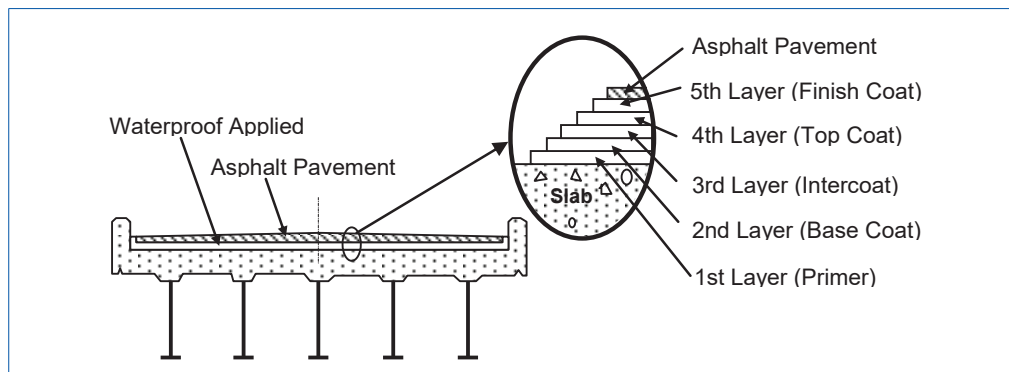


Figure 3.26 Layer composition for rubberized membrane

Table 3.14 Waterproofing on deck slab

i. Preparation of deck surface	ii. 1 st Layer (Primer)
	
After removal of the AC layer, the 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.	Primer coat shall be applied once or twice on the cleaned substrate using a roller brush. The coating is approximately 0.2 kg/m² and natural dried for more than 30 minutes until tack-free as specified by the manufacturer and approved by the Engineer.

iii. 2 nd layer (base coat)	iv. 3 rd layer (intercoat)
	
Base coat as 2 nd 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) as specified by the manufacturer and approved by the Engineer.	Intercoat, the 3 rd 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) as specified by the manufacturer and approved by the Engineer.
v. 4 th Layer (Top Coat)	vi. 5 th layer (Tack coat)
	
Top Coat, the 4 th 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) as specified by the manufacturer and approved by the Engineer	Tack Coat, 5 th 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) as specified by the manufacturer and approved by the Engineer
vii. Asphalt pavement	
For adequate protection of the waterproofing membrane, the application of the asphalt road surface is carried out after tack coat is cured.	
viii. Quality control	
For quality control, the Engineer shall carry out visual inspection to confirm compliance.	

(2) Asphalt compound membrane

Asphalt compound membrane is composed of layers as shown in Figure 3.26.

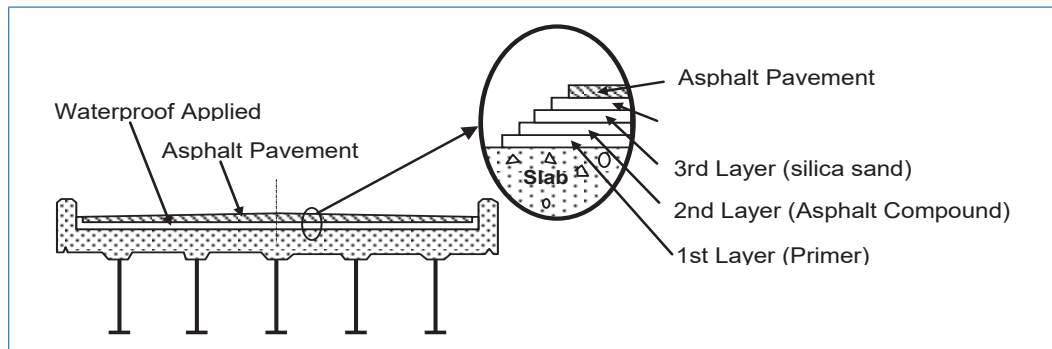
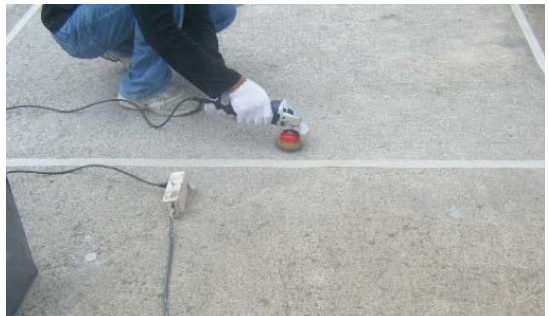


Figure 3.27 Layer composition of asphalt compound membrane

Table 3.15 Water proofing on deck slab (asphalt compound)

i. Preparation of deck 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.	
ii. 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/m² and natural dried for more than 30 minutes until tack-free. (Refer also to Manufacturer's instruction).	
iii. 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.	

iv. 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 0.7 kg/m²). The laying operation shall eliminate discontinuities in the membrane.



v. 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 3.0 kg/m². (Refer to the Manufacturer's instruction).



vi. 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



Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Bonding strength test and watertightness test as per the Standard Specifications for Bridge Repair in Kenya and any other applicable standard.

Measurements and Payment

Measurement shall be in square meters (m²).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for waterproofing the deck slab as detailed in plans and specifications.

3.3.1.8 Fast Setting Concrete for Continued Deck Slab

Definition

Fast setting concrete is a rapid set concrete that is a blend of ordinary and specialized cements, high quality graded aggregates and a unique combination of polymers and admixtures, and is used in continued deck slab connections where Reinforced Concrete Deck Girders (RCDG) bridges are to be constructed.

Continued deck slab connection is used to connect the deck slabs only.

Scope of Works

Where multiple RCDG bridges are designed as simple span with gaps between the spans, strengthening for stability of the structure will be required. Continued deck slab method is used for connection and to reduce the bridge maintenance work, and to maintain good performance.

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

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

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

Threaded rebar and rebar coupler are fabricated at the manufacturer. Rebar coupler material is high carbon steel.



Figure 3.28 Fast setting concrete for continued deck slab

Required Materials, Tools/Equipment & Personnel

- i. Required material
 - Cement
 - Aggregates
 - Rapid hardener admixture
 - Clean water
 - Epoxy Resin (Bonding coat to concrete)

- Anti-corrosion primer (bonding coat to rebar)
 - Rebars
 - Couplers
- ii. Required tools/equipment
- Sawing equipment
 - High pressure water equipment
 - Handy concrete breaker or jackhammer
 - Handy power chisel
 - Electric mixer with steel blade
 - Water container
 - Generator
 - Hydraulic pump system
 - Brush
- iii. Required personnel
- Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.16 Fast setting concrete for continued deck slab

i.	Removal of defective deck slab concrete
Defective concrete surface is cut by saw, forming vertical edges, and then removed using breaker and chisel. Rebars are examined for loss of section due to corrosion. If cross sectional area of the reinforcement has reduced by more than 20%, additional reinforcement is required.	
ii.	Setting of formworks
Soffit formwork for re-casting deck slab must be very rigid and well-supported to prevent the fast-setting concrete from sagging due to its own weight.	
iii.	Addition of longitudinal/transverse rebar
Longitudinal and transverse rebar to be provided shall be of same or bigger diameter than the existing rebar or as specified in the drawings issued by the Engineer.	
Spacing of rebar should be less than 150mm for durability and to avoid occurrence of bending cracks. Length of rebar should be around 1.4m for sufficient connection of	

each deck slab. For instance, if diameter of additional rebar to be used is 16mm, length of overlapping should be secured 640mm (16mm × 40 times) on each deck slab.

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

iv. Clean up inside formwork

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



v. Apply epoxy resin to existing concrete surface for proper bonding to fast-setting concrete

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



vi. Wet the formwork

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



vii. Mix with water

The material consists of special cement of pre-mixed type and sand for fast setting and non-shrink performance. According to the instruction by the manufacturer, amount of water and method of mixing shall be well organized.



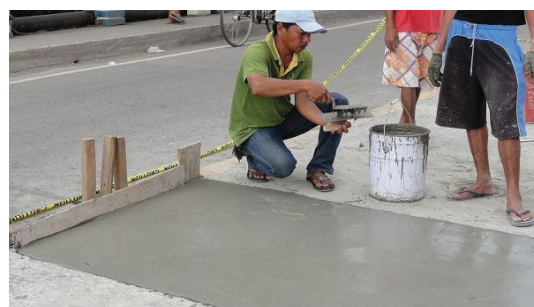
viii. Pour from lower side to upper position

Concrete is placed in the soffit for form-works through a suitable method.



ix. Finishing of surface, curing

After placing 1m length of fast-setting mortar, finishing of the surface should be started. Finish of unformed surfaces should be done by broom, wood float, or steel trowel to match the adjacent existing concrete. Ensure continuous curing after 4 hours of placing. Cure with water for a minimum of 7 days.



x. Quality control

The Engineer shall check the slump and compressive strength of the mix and where the crushing strength does not reach the required strength of 24N/sq.mm at 3 hours, the Engineer may order for NDT.

Monitoring and Evaluation

Performance Test – Compressive strength test, concrete bonding test and consistency test as per the Standard Specifications for Bridge Repair in Kenya and any other applicable standard.

Monitoring of repaired section by the Engineer.

Measurements and Payment

Measurement shall be in cubic meter (m^3).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for provision of fast setting mortar for continued deck slab as detailed in plans and specifications.

3.3.1.9 Protective Mortar

Definition

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

Scope of Works

The work involves application of protective mortar on concrete member susceptible to salt attack especially bridges located less than one (1) km from coastline.

There are two (2) options used in applying protective mortar:

- i) Apply three (3) coats of protective mortar to the surface of concrete member with severely deteriorated areas and/or repaired area.
- ii) Apply one (1) of protective mortar to the surface of concrete member for pre-ventive maintenance.



Figure 3.29 Protective mortar applied on deck slab bottom surface

Required Materials, Tools/Equipment & Personnel

- i. Required material
 - Polymer cement powder
 - Emulsion made of lithium nitrite and adhesive
 - Lithium nitrate
- ii. Required tools/equipment
 - Power disk grinder/cutter
 - Portable generator
 - Trowel
 - Brush/roller
- iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

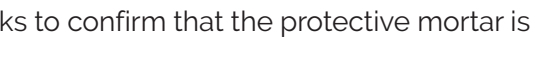
- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.17 Protective mortar

i. Surface preparation	
Entire surface of coating area should be cleaned by using cup wire brush and/or disc grinder.	
ii. Mixing the proportions	
Mix the polymer cement, lithium nitrate and emulsion in accordance with the manufacturer's instructions or as specified by the Engineer by use of weight batching method.	
iii. Application of PCM with Lithium Nitrite	
Apply and spread PCM with Lithium Nitrite on surface to be patched using trowel and/or brush.	
iii. Curing of PCM with Lithium Nitrite	
Curing with water shall be done for a minimum of 3 days.	
iv. Quality control	
The Engineer shall carry out the initial checks to confirm that the protective mortar is uniformly applied.	

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Compressive strength test, bonding strength test and consistency test as per the Standard Specifications for Bridge Repair in Kenya and any other applicable standard.

Measurements and Payment

Measurement shall be area in square metres (m²).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for application of protective mortar as detailed in plans and specifications.

3.3.1.10 Protective Coating

Definition

A protective coating is a layer of material applied to the surface of another material with the intent of inhibiting or preventing corrosion. A protective coating may be metallic or non-metallic. Commonly used materials in non-metallic protective coatings include polymers, epoxies and polyurethanes. Materials used for metallic protective coatings include zinc, aluminium and chromium.

Scope of Works

This method is applied to the deck slab, superstructure and the substructure. When bridge members are affected by carbonation, it is recommended that protective coating be applied as preventive maintenance.

Protective coating made from acryl urethane-based coating is effective against Carbon (iv) oxide, weather/UV rays, chemical and oil damage.

After repairing damage due to carbonation, protective coating shall be applied on the concrete member(s).

Required Materials, Tools/Equipment & Personnel

i. Required material

- Base Resin
- Hardener

ii. Required tools/equipment

- Power disc grinder/cutter
- Portable generator
- Paint roller and paint brush

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

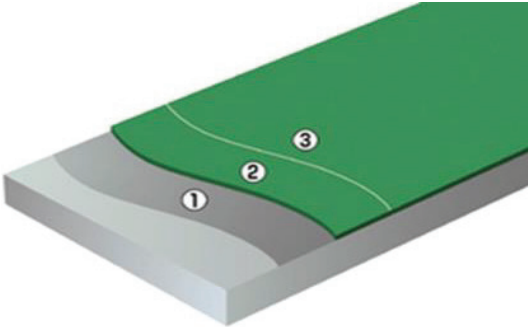
- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.18 Protective coating

i. Surface preparation Entire surface of coating area should be cleaned by using cup wire brush or disc grinder.	
ii. 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.	
iii. 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. The coats shall be applied to the thicknesses specified by the Engineer.	

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Bond strength test, chemical resistance test and watertightness test as per the Standard Specifications for Bridge Repair in Kenya and any other applicable standard.

Measurements and Payments

Measurement shall be in square meters (m^2).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for provision of protective coating as detailed in plans and specifications.

3.3.1.11 Recasting Concrete/Grout

Definition

This refers to any replacing, restoring, or renewing of concrete or concrete surfaces after initial placement.

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

Considering the position and scale of damage, the application of the recasting concrete and grout are classified according to the formwork types, such as the "Envelope Type" and "Mail Box Type,"

Envelope type formwork is open at the top for pouring concrete while the Mail box type formwork consists of holes or slit at its side for purposes of grouting or pumping mortar.

Mail box type formwork is further classified based on concrete volume, applied area and rebars arrangement with due consideration to cost performance.

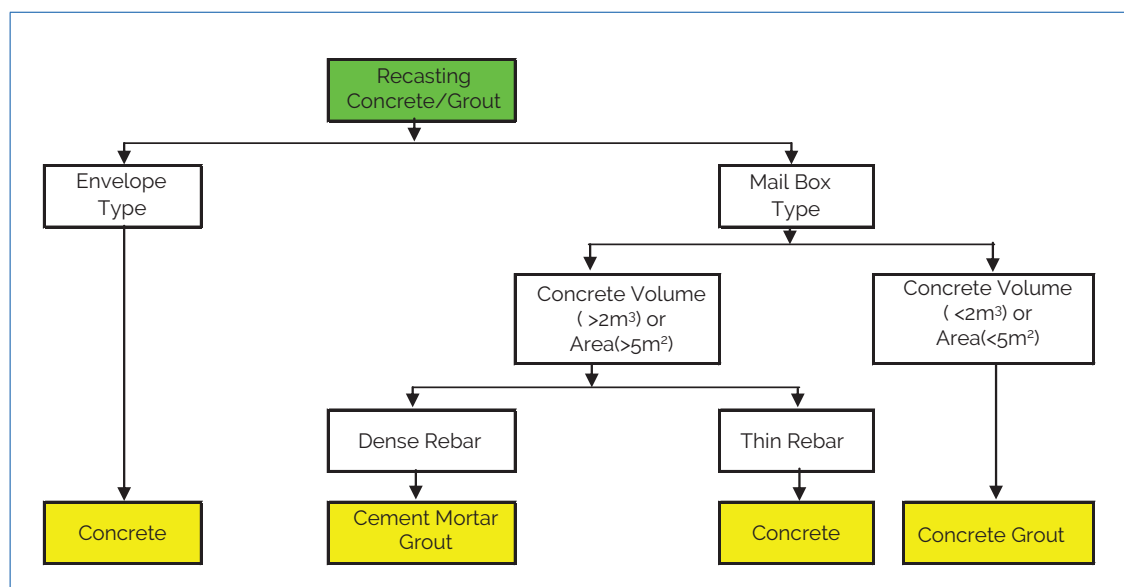


Figure 3.30 Flowchart of selecting material for recasting

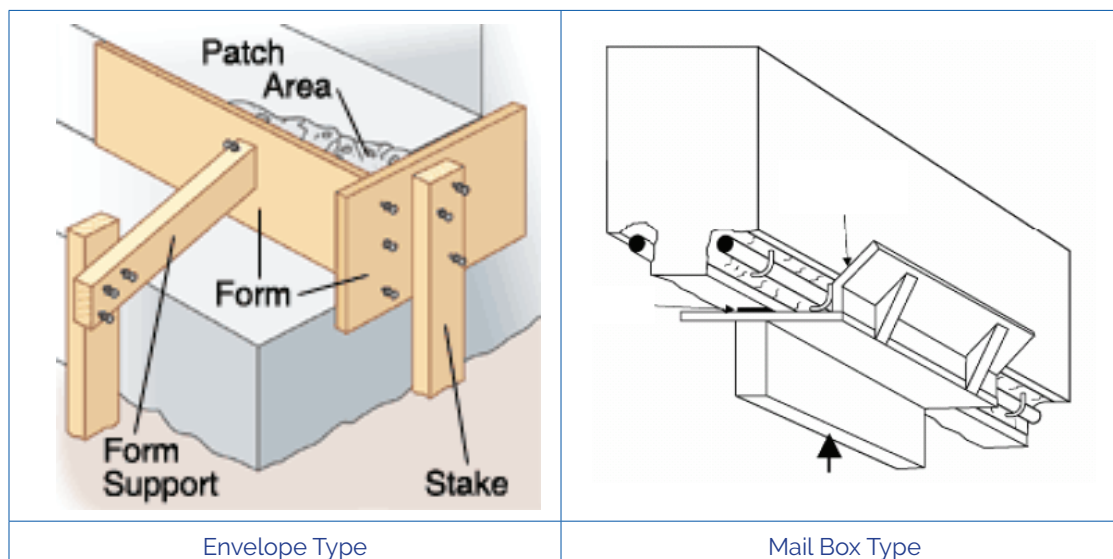


Figure 3.31 Types of formwork for recasting

Scope of Works

Recasting of the damaged area, by placing concrete or grouting mortar on the formwork is usually most suitable for severely damaged concrete, or for largely damaged areas with densely spaced rebar. Where concrete placing by vibration is a problem, grout and free flowing self-compacting concrete should be used to minimize the vibration required.

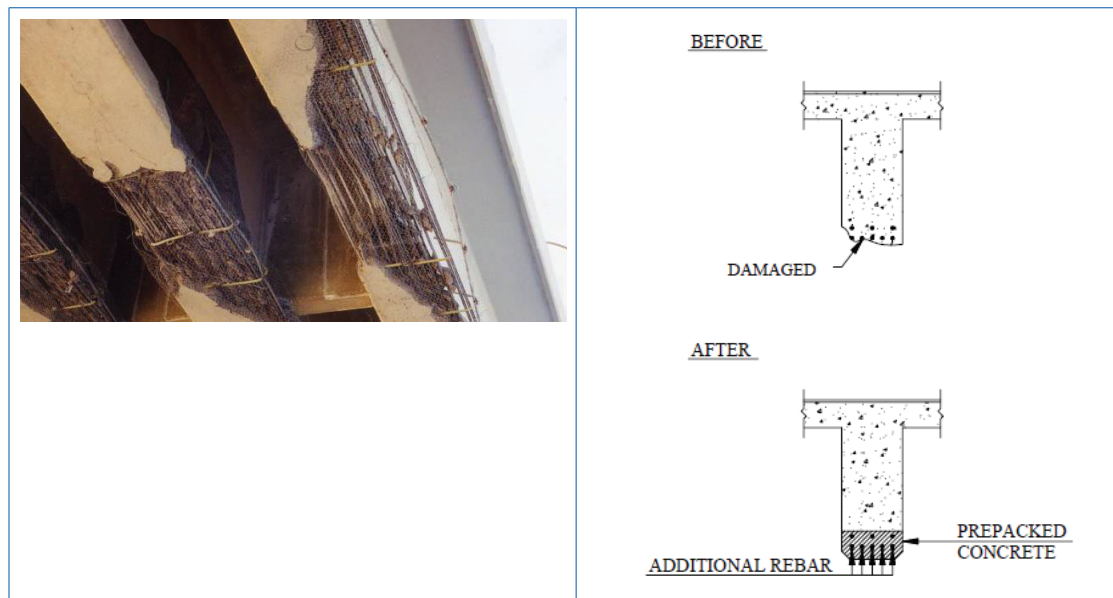


Figure 3.32 Recasting concrete illustration

Required Materials, Tools/Equipment and Personnel

- i. Required material
 - Admixtures for consistency
 - Reinforcing steel bars

- Bonding coat
 - Anti-Corrosion Primer
- ii. **Required tools/equipment**
- Formwork – timber/medium density fibreboard (MDF) and assorted fittings
 - Sawing equipment
 - High pressure water equipment
 - Handy concrete breaker or jackhammer
 - Handy power chisel
 - Concrete mixer 30 liters
 - Mortar mixer with pump (for mortar)
 - Concrete – cement, sand and aggregates
 - Concrete hoisting equipment
 - Vibrator
 - Trowelling tools
- iii. **Required personnel**
- Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

The work sequence for cement mortar grout involves concrete mixing, pouring and curing.

Table 3.19 Recasting concrete

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

Deteriorated rebars are cut up to the required lap length. New bars to be provided shall be of same or bigger diameter than the existing, taking into consideration the existing loading condition of the structure. The lap length is calculated as 50 times the new rebar diameter. The new rebar shall be tied to the existing bars using binding wires or by welding.



iii. Setting formworks.

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



iv. Preparation of old concrete and rebar

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



v. Mixing of mortar

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



vi. Mortar grouting

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



vii. Curing and removal of formworks

Curing with water for a minimum of 7 days.

Formworks for load bearing structural members shall remain in position for a minimum of 21 days.



vii. Quality control

All works shall be carried out in accordance with the specifications and Engineer's approval.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Compressive strength test, bonding strength test and soundness test as per the Standard Specifications for Bridge Repair in Kenya and any other applicable standard.

Measurements and Payment

Measurements shall be in tonnes of steel, cubic meters (m^3) of concrete and square meters (m^2) of formwork used.

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for recasting concrete as detailed in plans and specifications.

3.3.1.12 Carbon Fibre Sheet/Plate Bonding To Concrete Girder

Definition

Carbon fibre possesses a high tensile strength, higher modulus of elasticity and it is considered an alternative for strengthening bridge girders by increasing its load bearing capacity. It shall be used in form of Carbon Fibre Sheet (CFS) or Carbon Fibre Plate (CFP).

Scope of Works

CFS/CFP for reinforced concrete girder repair and strengthening systems are combination of carbon fibre material and resins, such as epoxies and other adhesive materials, acting as a composite material to enhance the capacity and extend the life of concrete structures. The role of the resin is to serve as an adhesive bond to the concrete surface and facilitate the transfer of stresses to and from the CFS/CFP.

As shown in Figure 3.33, the section of $L/4$ in span from both ends is applied with CFS as protection against shear cracks (see Figure 3.34 [1]) while the centre section of $L/2$ in span is applied with CFP for protection against flexural cracks (Figure 3.34[2]) caused by live load, where L is the effective span length.

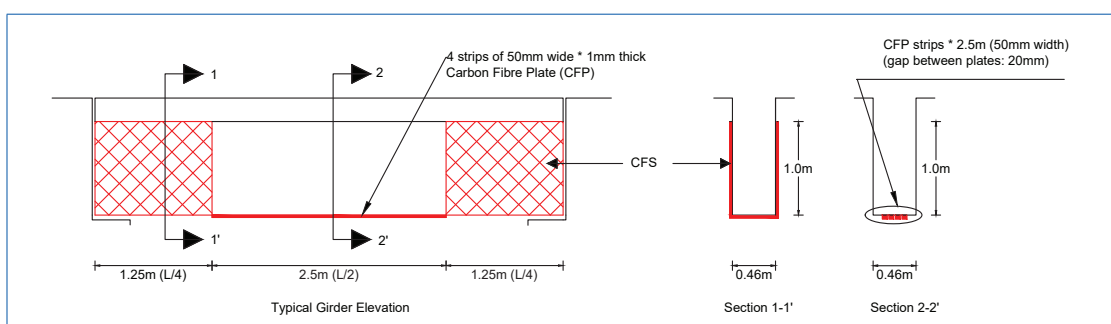


Figure 3.33 Arrangement of carbon fibre sheet/plate

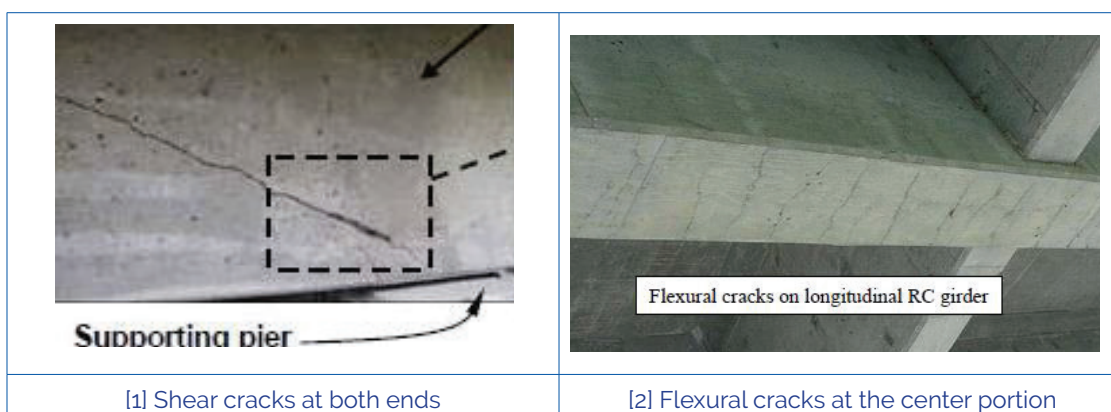


Figure 3.34 Shear and flexural cracks

Required Materials, Tools/Equipment and Personnel

i. Required material

- Carbon fibre products
- Carbon fibre sheet
- Carbon fibre sheet strip
- Carbon fibre plate
- Epoxy materials
- Epoxy primer
- Epoxy putty
- Epoxy resin

ii. Required tools/equipment

- Abrasive sandblaster
- Air compressor
- Disc grinder
- Portable generator
- Paint roller/brush
- Applicator

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

A. For CFS

Table 3.20 Carbon fibre sheet work sequence

i. Preparation of concrete surface Disc grinder or abrasive sandblasting is used to clean the concrete surface and to ensure that the surface roughness is even and smooth. To avoid pollution impact to soil and water, dust, cement, paint and other contaminants were contained by covering the bridge with plastic sheeting.	
ii. Application of primer Primer resin soaks into the surface of concrete, resulting in increased strength of the concrete surface and improved bonding with CFS.	

iii. Adjustment of unevenness with putty

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



iv. Application epoxy resin for undercoat

Using roller, epoxy resin is applied to the concrete as adhesive to bond with the CFS. It forms a molded composite by permeating into the CFS.

v. Installation of CFS (1st layer)

Properly aligned CFS are installed to the resin coated concrete surface to strengthen the section. Press the CFS using deformed roller, starting from the center toward the edges.



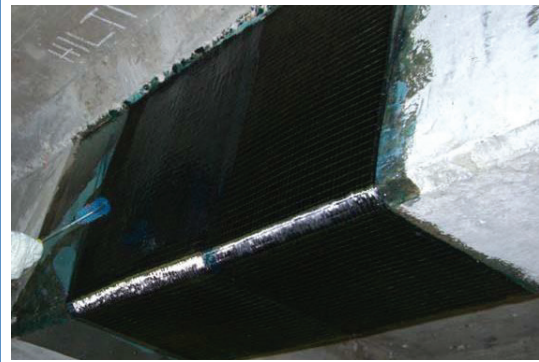
vi. Squeezing out of entrapped air

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



vii. Over coating resin application

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

**viii. Installation of CFS (2nd layer)**

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

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

**ix. Surface protection**

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



B. For CFP

Table 3.21 Carbon fibre plate work sequence

i. Preparation of concrete surface Disc grinder or abrasive sandblasting is used to clean the concrete surface and to ensure that concrete surface is even and smooth.	
ii. Application of primer Primer resin soaks into the surface of concrete, resulting in increased strength of concrete surface and improves the bonding with CFP.	
iii. Adjustment of unevenness with putty Any concave, pores, gaps on the concrete surface must be smoothed with epoxy putty. After the putty becomes tack-free, it is required to roughen the surface with sandpaper, then cleaned.	
iv. Application of epoxy resin on CFP In order to reduce the formation of voids, epoxy-based adhesive is applied to the CFP using an applicator to bond, forming a curved profile measuring approximately 3 mm in the center and 1 mm on the edges.	

v. Installation of CFP Properly aligned CFP is installed longitudinally to the adhesive coated concrete surface.	
vi. Squeezing out of entrapped air For complete impregnation, entrapped air is squeezed out the CFP using a roller, before the applied adhesive sets.	
vii. Pressure attachment of CFP Set at position of the girder, then press using wooden anchor frame and set bolts for curing.	

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Carry out tensile test, shear test and adhesive tests as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Frequency of Tests – Tests can be done one year after installation of the additional plate and 5 years subsequently during the detailed inspection.

Measurements and Payment

Measurements shall be in square metres (m²).

Payment shall include full compensation for provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.3.1.13 Jacketing with Concrete

Definition

Jacketing is a method of structural retrofitting and strengthening. It is used to increase load bearing capacity following a modification of the structural design or to restore structural design integrity due to a failure in the structural member. This technique is used on vertical surfaces such as walls, columns and other combinations such as beam sides and bottoms. It consists of added concrete with longitudinal and transverse reinforcement around the existing column.

Scope of Works

Concrete jacket as shown in Figure 3.35 is mainly applied to substructure that has deteriorated concrete due to corrosion of rebar. It should be noted that splash zone portions of bridge concrete piles in marine environment are more exposed to corrosion. Although provision of jackets could delay further chlorides from entering the pile, this does not guarantee complete mitigation of corrosion to the rebars.

Steel jacketing remains an effective alternative for strengthening piers or piles against structural failure, however, it is not included in the scope of this manual.

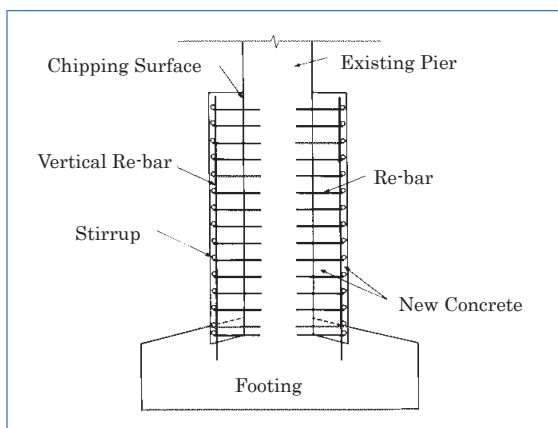


Figure 3.35 Concrete jacketing

The following are the jacketing methods available:

1. Reinforced concrete jacketing
2. Steel jacketing
3. Fibre reinforced polymer jacketing
4. Glass fibre reinforced polymer jacketing
5. Near-Surface Mounted (NSM) Fibre-Reinforced Polymer (FRP) Jacketing
6. Hybrid Jacketing
7. Shape Memory Alloy (SMA) Wire Jacketing



Figure 3.36 Concrete jacket for pier repair

In this section, two methods of jacketing, namely concrete jacket and steel jacket, are discussed.

Concrete jacket is applied to protect the deteriorated concrete due to corrosion of rebars, damage due to rapid water flow or broken due to continuous impact from materials flowing in the channel such as drift woods. Concrete jacket should be basically placed above water level. If the damaged portion is submerged to water, cofferdam is necessary to achieve a dry condition during jacketing. To minimize cofferdam, related repair works are either carried out while water is at low level in the dry season, or using underwater concrete.

Required Material, Tools/Equipment and Personnel

i. Required materials

- *Concrete with fine aggregate*

A suggested mix design for small scale repairs is given below as reference. These quantities will make about 0.03 m³ of concrete and could be fully accommodated in a small mixer.

- a. Cement
 - Portland cement 13.0 kg
 - Admixture 0.5 kg (Silica fume)
- 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

- *Formwork*

- a. Steel formwork (Circular)
- b. Plywood formwork

ii. Required tools/equipment

- Drilling machine to concrete
- Concrete vibrator

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

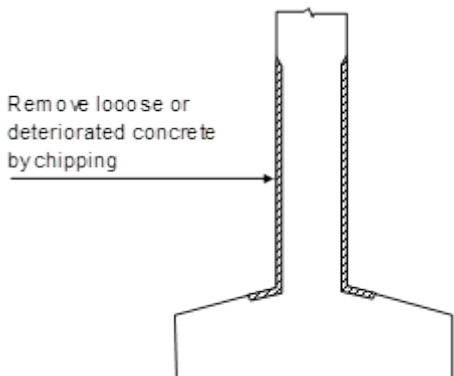
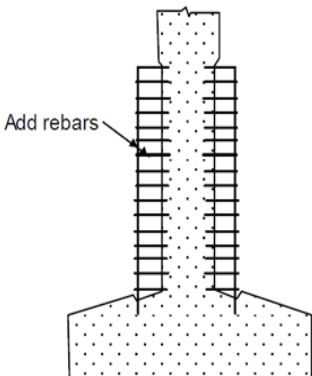
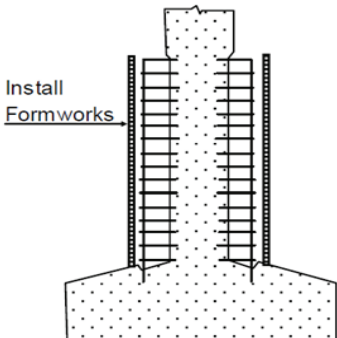
- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

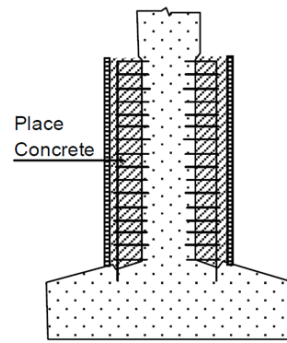
Work Sequence

Table 3.22 Jacketing with concrete

i. Removal of deteriorated concrete All loose or deteriorated concrete shall be removed. Surface cracks shall also be removed by chipping. Hammer sounding shall be done to locate delaminated areas. When corroded reinforcing steel is exposed during concrete removal, the corroded bars shall be further exposed by chipping until clean un-corroded steel is exposed.	 Remove loose or deteriorated concrete by chipping
ii. Addition of rebar Additional rebars are anchored into drilled holes in the concrete, and placed in conformity with the requirements shown on drawings. Heavily corroded rebar shall also be replaced as directed by the Engineer. Clear concrete cover to rebar, for piers and piles, shall be 40 mm in normal environment, and 55 mm in marine environment.	 Add rebars
iii. Setting-up formworks Formwork for concrete jacket is commonly circular or rectangular in shape. This formwork must be very rigid and well-supported to maintain the shape and the required covering of the new concrete. It should also be able to withstand pumping forces if concrete is to be pumped and vibrated.	 Install Formworks

iii. Placing of concrete

Concrete is placed in the formworks through a suitable method and compacted well using internal or external vibrators. Surfaces shall be finished using broom, wood floating, and steel trowelling to match the adjacent existing concrete.



iv. Curing of concrete

Continuous water curing using wetted cotton mat is preferable to help slow down drying. Formworks for load bearing structural members shall remain in position for a minimum of 21 days.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Bonding strength test, compressive strength test and consistency test as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payment

Measurements shall be in tonnes of steel, cubic meters (m^3) of concrete and square meters (m^2) of formwork used.

Payment shall include full compensation for provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.3.2 Major Repair Methods in Steel Bridges

Major repair methods in steel bridges are; repainting, steel plate adding, carbon fibre plate bonding, tightening / retightening of high-tension bolt, application of anti-corrosion paint, provision of stop hole and repair to heat damages.

The defects addressed in this section of the manual are listed in Table 3.23.

Table 3.23 Defects addressed in major repairs to steel bridges

Classification	Repair / Strengthening Method	Method	Defects Addressed
Major Repairs	Repair	Repainting	Paint deterioration Corrosion
	Strengthening	Steel Plate Adding	Excessive deformation, deflection/vibrations Fatigue Section loss
	Strengthening	Carbon Fibre Plate Bonding	Excessive deformation, deflection/vibrations Fatigue
	Repair	Tightening / Retightening Of High-Tension Bolt	Missing bolts Loose bolts Unfixed parts
	Repair	Anti-Corrosion Paint	Paint deterioration Corrosion
	Preventive	Stop Hole	Crack
	Repair	Repair of heat damage on steel bridge	Heat damage
	Repair	Replacement of member (Section 3.4)	Missing parts Section loss Fracture Buckling

3.3.2.1 Repainting

Definition

This refers to the application of a new coat of paint to a surface that was initially painted.

Scope of Works

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.

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

Table 3.24 Type of paintings

Photography	Rust Condition	Interventions	Type of Paint
	Corrosion is very severe and coating film is not visible. 1 st grade surface preparation is necessary.	Repainting	Epoxy Zinc Rich primer and Polyurethane Aluminum paint
	Corrosion is severe and coating film is visible but almost deteriorated due to corrosion. 2 nd grade surface preparation is necessary.		Modified epoxy Polyimide paint and Polyurethane Aluminum paint

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

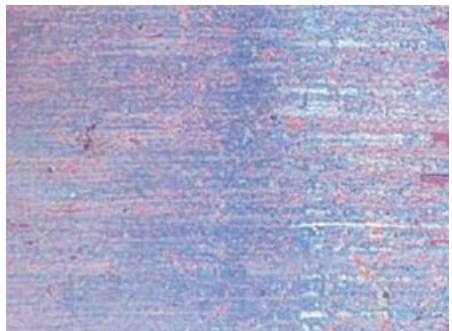
The 1st grade surface preparation shall be applied if the rust is very severe and coating film is not visible.

The 2nd grade surface preparation shall be applied if the rust is severe and coating film is visible but almost deteriorated.

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 under bottom flanges, which are usually subjected to severe corrosion.

Table 3.25 Preparation grades of the surface of corroded steel plate

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

Required Materials, Tools/Equipment and Personnel

i. Required materials

- Epoxy zinc-rich primer
- Modified epoxy polyimide paint
- Polyurethane paint – thinner

ii. Tools/equipment

- High-pressure water jet spray
- Water bowser
- Generator
- Disc grinder
- Sand blast machine if required
- Air compressor
- Wire brush and scraper
- Paint roller and paint brush
- Sandblasting sheet

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence



Figure 3.37 Scaffolding for safe repair works and environmental protection

Table 3.26 Repainting

i. Preparation of steel surfaces	
The steel bridge shall be washed with fresh water. 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. If sand blasting is required, steel girder shall be covered with plastic sheet to avoid pollution impact to surrounding soil and water.	
ii. Filling voids	
During surface preparation, severely corroded surface shall be filled with epoxy putty to fill any existing voids.	
iii. Painting	
Paint shall be applied on the steel surface using paint brush and paint roller, to ensure smooth surface. It should be strictly executed to keep a continuous, uniform film of specified thickness as directed by the Engineer. Paint consists of one layer of primer and two layers of polyurethane aluminium paint.	
	Primer
	
	Paint (2 nd Layer)

iv. Checking of paint thickness

Measure coating film thickness using paint/coating thickness meter.



v. Historical record marking

This shall be marked on the web plate, near the bearing, as shown and as approved by the Engineer.



Table 3.27 Paint Record Table

Painting Date	[Date]	
Paint System		
Painting Company	Primer	[Painting Company]
	Undercoat	
	Intermediate Coat	
	Top Coat	
Paint Material	Primer	
	Undercoat	
	Intermediate Coat	
	Top Coat	
Top Coat Colour	[Colour Code]	
Paint Manufacturing Company	Primer	[Paint Manufacturing Company]
	Undercoat	[Paint Manufacturing Company]
	Intermediate Coat	[Paint Manufacturing Company]
	Top Coat	[Paint Manufacturing Company]

Monitoring and Evaluation

Monitoring of repainted section by the Engineer.

Performance Test: Pigment or coating depth test, abrasion resistance, adhesion and resistance tests (water, chemical and fire) as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payment

Measurement shall be in square metres (m²).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for repainting as detailed in plans and specifications.

3.3.2.2 Steel Plate Adding

Definition

This refers to strengthening of the lower flange section to restore the original designed section area. It is mainly applied to steel girders that are prone to corrosion which could accelerate consequently leading to section loss, especially of the bottom flange plates and sections near bearings.

Scope of Works

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

In order to restore the lost strength, additional steel/angular 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.

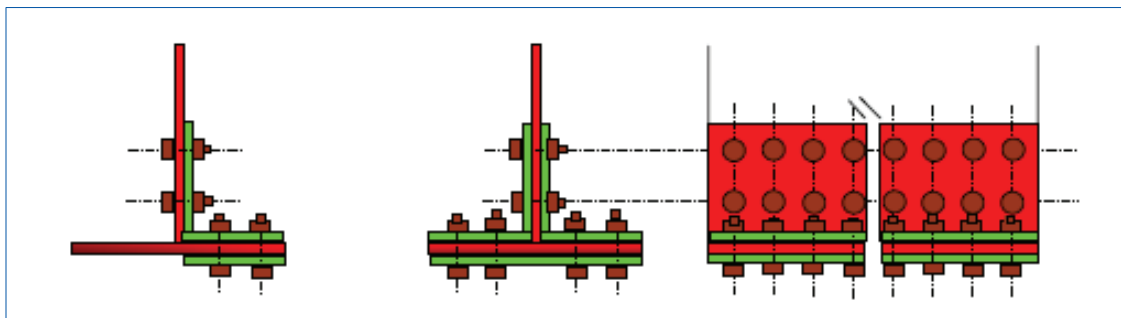


Figure 3.38 Steel plate adding

Required Materials, Tools/Equipment and Personnel

- i. Required material
 - Flat plate and angular plate
 - High tension bolt (HTB)
 - Anchor bolts
 - Epoxy putty
 - Paint
- ii. Required tools/equipment
 - Welding machine
 - Electric drill
 - Epoxy injection pump with accessories

- Disc grinder
 - Portable generator
 - Paint roller/brush
- iii. **Required personnel**
 Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. Surface preparation

All surfaces to be provided with additional steel plates shall be cleaned of all rust, dirt, oil or grease, and other foreign substances.

Surfaces to be painted shall be grinded to increase adhesion of the new paint required.

The grade of surface preparation shall conform to section 3.3.2.1 work sequence (i).

ii. Surface treatment

After surface preparation, epoxy putty will be applied to level the surface of the existing steel plate which may have holes and dents resulting to loss of cross-section to recover its original thickness and shape.

iii. Holes for HTB

Templates for bolt holes for the additional flat plate or angular plate, shall be fabricated and prepared based on the actual positioning required at site.

Holes for the HTB shall be drilled through the plates using portable electric drill or electric coring drill as stipulated in the specifications and approved by the Engineer.

iv. Assembling flat plate and angular plate

After installation, each HTB shall be fastened with electric fastener.

v. Epoxy caulking

Gaps found between the new plate and existing steel plate shall be filled with epoxy caulking as per the manufacturer's specifications and as approved by the Engineer..

vi. Tightening high tension bolts.

After the first fastening as per (iv) above, yellow mark is painted on each HTB in order to identify the initial orientation.

HTB shall be tightened using rotation angle method as means of quality control to maintain design tension stress.

The limit of rotation angle for tightening shall be $120^{\circ} \pm 30^{\circ}$ from the marking as specified and approved by the Engineer.

vii. **Painting**

Polyurethane aluminum paint shall be applied to the installed steel plates and HTB.

viii. **Historical record marking**

Historical record for the repair measure performed shall be marked on the web plate near the bearing as described in section 3.3.2.1 Work sequence (v).

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Tensile strength test, shear strength test and torque test as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and payment.

Measurement shall be in tonnes.

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for strengthening the steel plate adding as detailed in plans and specifications.

3.3.2.3 Carbon Fibre Plate (CFP) Bonding

Definition

It is the application of carbon fibre plates to steel bridge member surfaces using epoxy resin adhesives.

Scope of Works

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

Repair method using carbon fibre plate (CFP) bonding to steel plate provides the same function as the additional steel plates presented in Section 3.3.2.2 of this manual.

CFP method involves simple application of bonding to steel bridge surface using epoxy resin adhesive. In case of section loss or defective holes, the purpose of bottom flange repair shall be to restore the original strength of the section by installing required area of CFP as shown in Figures 3.39 and 3.40.

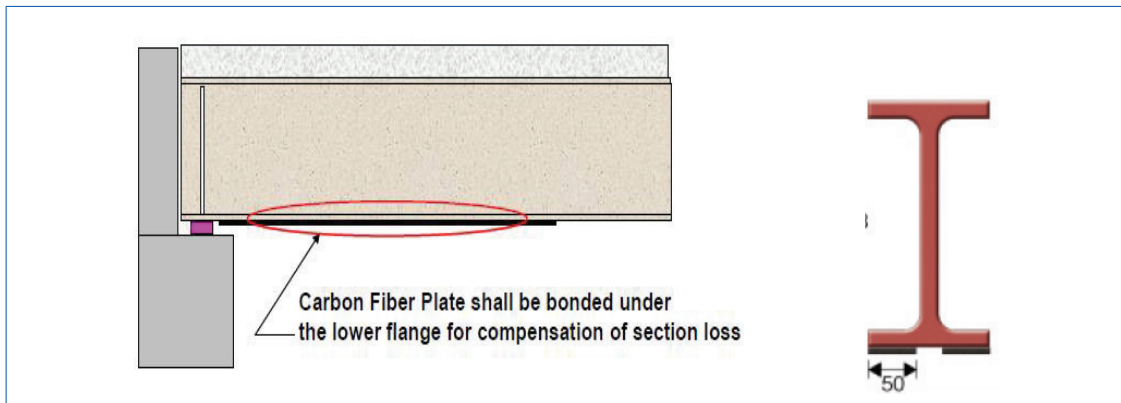


Figure 3.39 CFP added at bottom flange

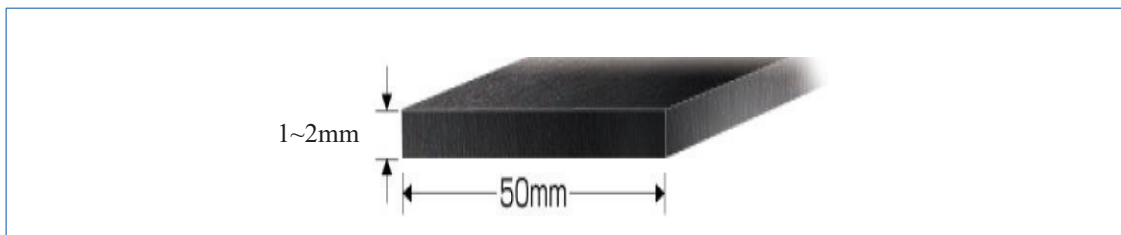


Figure 3.40 Carbon fibre plate size

CFP shall be installed at the portion of existing steel members where section loss is more than 20% in order to restore the lost strength. This repair method shall be further supplemented by repainting or by application of anti-corrosion coating.

Required Material, Tools/Equipment and Personnel

i. Required materials

- Epoxy putty
- Carbon fibre plate

ii. Required tools/equipment

- Electric disc grinder
- Generator
- Wire brush, scraper etc.,

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.28 Carbon fibre plate bonding

i. Surface preparation of steel plate All surfaces to be provided with carbon fibre plates shall be cleaned of all rust, dirt, oil or grease, and other foreign substances. The grade of surface preparation shall conform to section 3.3.2.1 Work sequence (i)	
ii. Adjustment of unevenness with putty Epoxy putty shall be applied to level the surface of the existing steel plate and recover its initial thickness and shape. The surface shall then be smoothed using 60-100 sandpaper.	
iii. Application of epoxy resin for undercoat Epoxy resin shall be applied using a roller as adhesive to bond to CFP, thus forming a molded composite through impregnation into the CFP.	
iv. Carbon plate bonding An epoxy-based adhesive shall be applied to the CFP using an applicator to bond. To reduce formation of voids, the adhesive is spread to form a curved profile that measures 3 mm at the center and 1 mm at the edges. CFP should be installed manually by applying uniform pressure along the longitudinal centreline.	

v. Removal of entrapped air

For effective impregnation, entrapped air shall be squeezed out of the strips using a roller, before the adhesive sets.



vi. Clamping of CFP

The bonded CFP shall be clamped to the member for a minimum of 24 hours to allow the initial resin saturate to set.



Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Carry out tensile test, shear test and adhesive tests as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payment

Measurement shall be in linear meters (m).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for the works as detailed in plans and specifications.

3.3.2.4 Replacement of High Tension Bolts (HTB)

Definition

This refers to replacement of missing or retightening of loose High-Tension Bolt (HTB) connection for steel elements of a bridge during maintenance.

Scope of Works

This repair method is applied to missing bolts, severely corroded bolts and for loosened fasteners exceeding 10% of the total number of bolts per location on a steel element. Damaged bolts found to exhibit delayed fatigue fracture need also to be replaced.



Figure 3.41 Sample bolt with delayed fatigue fracture

Required Material, Tools/Equipment & Personnel

- i. Required material
 - HTB
 - Grease
 - Anti-rust spray
 - Yellow paint
- ii. Required tools/equipment
 - Torque wrench (calibrated)/electrical impact wrench/special fastener for HTB.
 - Paint brush
 - Hammer
 - Spanner
 - Electric drill
 - Acetylene gas cutter
- iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.29 Replacement method of HTB

Method \ Item No.	No.1	No.2	No.3
	Replace Bolt only	Chip-off haunch	Break Deck Slab
Outline of method	Remaining Nut still used  Replace Bolt only		
	- Remove severely corroded HTB from top flange - Rotation angle method is applied to fasten HTB as quality control	- Chip of concrete from ① or ② shown - Replace bolts and nuts - Pour non-shrink mortar at chipped off locations	- Break deck slab from top surface - Replace bolts and nut - Pour non-shrink mortar for broken portion of the deck

i. Removal of High Tension Bolt

Removal of severely corroded HTB shall be carried out using the electric fastener, hammer, wrench and spanner with long handle. If the former is unsuccessful, the HTB shall be cut using acetylene gas.



Figure 3.42 Electric fastener for HTB

ii. Surface preparation

All the adhering rust, scale, dirt, grease or other foreign material shall be removed after rinsing with water.

iii. Fastening HTB

Upon installation of HTB, each shall be fastened using electric fastener. Yellow marking shall then be painted on each HTB in order to distinguish the initial orientation.

iv. Quality control of HTB fastening

HTB shall be fastened using rotation angle method as a means of quality control to meet the required design tensile stress. The fastening rotation angle shall be $120^{\circ} \pm 30^{\circ}$ from the location of the yellow marking.

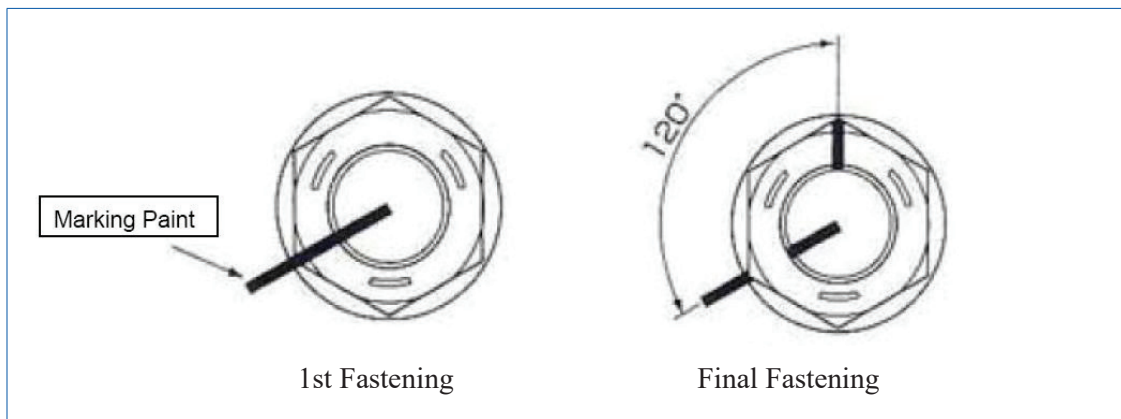


Figure 3.43 Method of HTB fastening

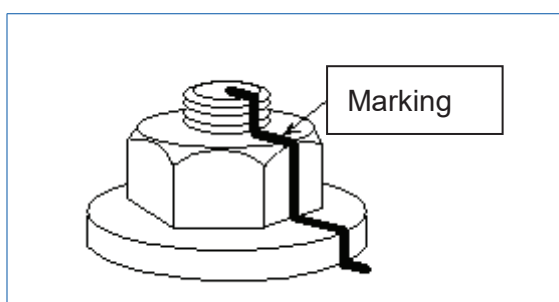


Figure 3.44 HTB marking

v. **Finishing surface preparation**

After fastening all the HTB, grease or other oil material shall be removed using solvent material. New HTB shall be covered with grease to control rotation friction.

vi. **Painting**

If repainting of the finally fastened HTB is necessary to refer to the section on repainting, for polyurethane aluminium paint (repainting) and anti-corrosion paint, respectively, for the required appropriate paint material.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Tensile strength test, shear strength test and torque test as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payment

Measurements shall be in number of bolts.

Payments shall include full compensation for supplying all labour, materials, tools, equipment, and incidental items. This also includes furnishing, preparing, fabricating, transporting, placing, fastening and greasing of the HTB.

3.3.2.5 Anti-Corrosion Paint

Definition

Anti-corrosion paint is ideally applied to protect solid metal surfaces and, in some occasions, various non-metals.

Environmental exposure has a great impact on the effectiveness and suitability of an anti-corrosion paint.

Anti-corrosion paint is applied to maintain good surface condition of bridges situated in severely active environment, subjected to wind-borne sea water spray.

It was observed that progressive rust was arrested after application of high alkaline atmosphere special anti-corrosion paint. As a minimum coating requirement, the total anti-corrosion paint weight should exceed 1.0kg/m^2 for two coats.



Figure 3.45 Lunga Lunga Bridge along the Kenyan coast

Scope of Works

Anti-corrosion paint shall be applied to the portion of steel plate that has section loss of more than 10% but less than 20%. This repair method is also applied in combination with repainting repair method.

Required Materials, Tools/Equipment and Personnel

- i. Required materials
 - Emulsion
 - Compound
- ii. Required tools/equipment
 - Hand mixer
 - Paint roller and paint brush
 - Wire brush
 - Electric grinder
 - Portable generator
- iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. Preparation of steel surface

Adhering rust, scale, dirt, grease or other foreign material shall be removed to clean the identified surfaces after rinsing with water.

The 3rd Grade surface preparation is commonly adopted for the steel surface, using wire brush and electric disc grinder.

Existing undamaged coating film shall be maintained. It is also not necessary to completely remove rust using the disc grinder, as this will be arrested after application of the anti-corrosion paint.

The surface preparation shall be approved by the Engineer before applying anti-corrosion paint.



Figure 3.46 Corroded steel surface preparation for painting

iii. Mixing paint

Proper mixing of compound and emulsion is vital to attain expected quality of this paint. A mixing ratio between emulsion and compound shall be in accordance with the manufacturer's specifications.

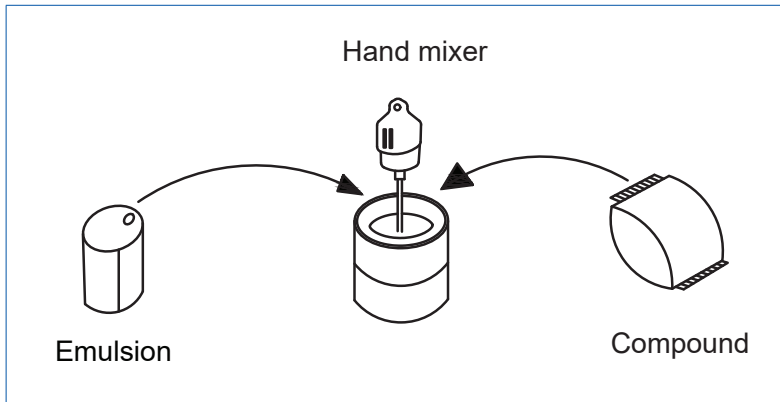


Figure 3.47 Mixing materials for anti-corrosion paint

iv. Painting

Painting shall be carried out as per section 3.3.2.1 work sequence for painting.

For consistency, the coating film thickness shall be measured under dry condition, using a thickness gauge.



Figure 3.48 Painting

v. **Curing**

The coating film dries within a day, under room temperature (25 degrees celcius). During rainy season, drying time may extend. Once the coating dries, water is not expected to affect the surface.

vi. **Inspection**

The paint film thickness shall be measured using thickness gauge to verify consistency of thickness. The minimum thickness allowed shall be 70% of the required value, similar to the quality control adopted for ordinary painting system as per the specifications and approved by the Engineer.

vii. **Historical record making**

This shall be marked on the web plate, near the bearing, as shown in Table 3.27 and as approved by the Engineer.

Monitoring and Evaluation

Performance Test: Pigment or coating depth test, abrasion resistance, adhesion and resistance tests (water, chemical and fire) as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Monitoring of painted section by the Engineer.

Measurement and Payment

Measurement shall be by square meters (m²).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for painting the structure as detailed in plans and specifications.

3.3.2.6 Stop Hole

Definition

This method is one of useful countermeasures against fatigue cracks originated in steel members. It involves drilling a hole at the edge of fatigue crack for reduction of stress concentration. It should be combined with another method like supplementing steel plate bonding method.

Scope of Works

The stop hole method involves drilling a hole at the end of a crack to stop propagation. A bolt is then placed in the drilled hole to compensate for the lost section.

This method is applied as an emergency measure before applying a permanent solution.

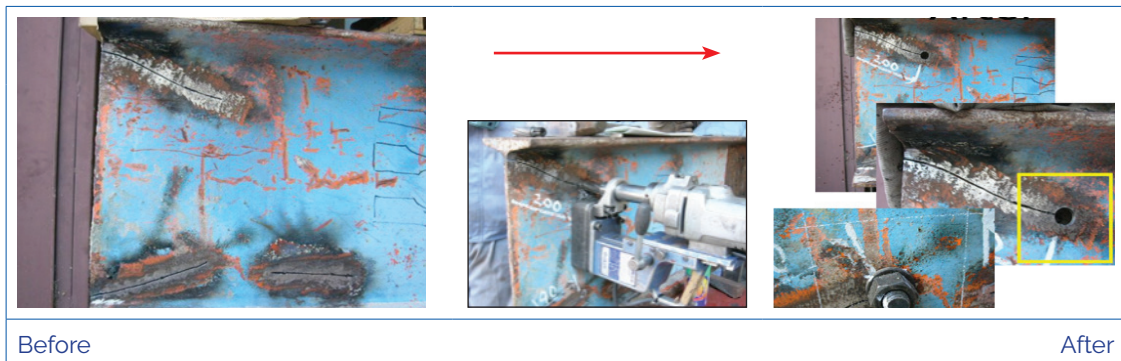


Figure 3.49 Stop hole

Required Materials, Tools/Equipment and Personnel

- i. Required materials
 - Drill bit
 - Bolts, washers and nuts
 - Fuel
- ii. Required materials/equipment
 - Electric drill
 - Generator
 - Torque wrench
- iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. Investigate the end of the crack,
- ii. Drilling hole at the edge of the crack,
- iii. Removing the burrs and surface treatment around the hole,
- iv. Fix and tighten the suitable sized bolt and nut with washers using the torque wrench.

Measurements and Payment

Measurement shall be in the numbers (No.) of holes drilled as instructed by the Engineer.

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for crack repair of fatigue cracks as detailed in plans and specifications.

3.3.2.7 Repair of Heat Damage on Steel Bridge

Definition

Heat damage on a steel bridge refers to adverse changes in the properties and structural integrity of the steel components caused by exposure to high temperatures. These elevated temperatures can result from various sources such as fire, hot work, prolonged exposure to high ambient temperatures, or other heat-related incidents. Heat damage can adversely affect the steel's mechanical properties, structural stability, and overall performance, posing a significant threat to the safety and functionality of the bridge.

Heat damage on a steel bridge can manifest in several ways, including: softening and weakening, distortion and warping, brittleness and cracking, color changes, microstructure alteration, loss of ductility.

Repairing heat damage on a steel bridge involves addressing any structural or cosmetic damage caused by high temperatures, such as fire or excessive heat. The severity and extent of the damage will determine the specific repair procedures needed.

Scope of Works

- Remove the damaged section,
- Reinstall/replace the damaged section,
- Finish to match the initial design.

Required Materials, Tools/Equipment & Personnel

i. Required materials

- Steel section and accessories
- Paint

ii. Required tools/equipment

- Grinder
- Generator
- Welding machine
- Oxy-acetylene torches
- Scaffolding
- Support planks

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. **Cleaning and surface preparation**

The damaged areas of the steel shall be cleaned to remove any contaminants, debris, or loose material. Appropriate cleaning methods such as power washing or abrasive blasting to prepare the surface for repairs shall be applied as specified and directed by the Engineer.

- ii. **Removal of damaged material**

Remove severely damaged or weakened sections of the steel that cannot be repaired effectively. This shall involve cutting out the damaged sections using cutting tools such as plasma cutters, oxy-acetylene torches, or other appropriate equipment.

- iii. **Welding and structural repairs**

Weld new steel sections or plates to replace the removed or damaged portions. Ensure that the welding process is performed by skilled welders, following proper welding procedures and adhering to welding standards for structural integrity.

- iv. **Stress relief and annealing**

If needed, subject the repaired sections to stress relief annealing, a heat treatment process, to relieve internal stresses and improve the material's structural properties.

- v. **Surface finishing and protection**

Finish the repaired areas to match the existing structure's surface finish. Apply appropriate coatings, paints, or protective layers to prevent corrosion and enhance the steel's durability in accordance with the section 3.3.2.1 of this manual and approved by the Engineer.

- vi. **Quality inspection and testing**

Conduct Non-Destructive Testing (NDT) or other relevant tests to ensure the repairs meet the required quality and safety standards. Common NDT methods for steel include ultrasonic testing, magnetic particle testing, and dye penetrant testing.

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Weld fillet quality test and finishing tests (coatings and paintings) as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be as instructed by the Engineer.

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for the repair of heat damaged steel element as detailed in plans and specifications.

3.3.3 Major Repair Methods in Timber Bridges

Major repair methods in timber bridges are: repair of splitting of timber sections by split banding, repair of severely split timber by anti-split bolt, repairing splitting timber stringer, repairing split and rotten corbels, replacing severely split spiking planks, replacing timber crosshead/cap wales/half caps, repairing timber deck, repairing timber kerbs, replacing timber corbels and installation of flashing.

The defects addressed in this section of the manual are listed in Table 3.30.

Table 3.30 Defects addressed in major repairs to timber bridges

Classification	Repair/Strengthening Method	Method	Defects Addressed
Major Repairs	Repair	Repair of splitting of timber sections by split banding	Split
		Repair of severely split timber by anti-split bolt	Split
		Repairing splitting timber stringer	Split
		Repairing split and rotten corbels	Rot Split
		Replacing severely split spiking planks	Split
		Replacing timber crosshead/cap wales/half caps	Rot Split
		Replacing timber crosshead/cap wales/half caps	Crack Rotting Split
		Repairing timber deck	Crack Rotting Split

Classification	Repair/Strengthening Method	Method	Defects Addressed
Major Repairs	Repair	Replacing timber corbels	Crack Rotting Split
	Preventive	Installation of flashing	Rotting
	Repair	Replacement of structure (Section 3.4)	Crack Rotting Rattling of member Abnormal deflection Inclination Abnormal alignment

3.3.3.1 Repair of Splitting of Timber Sections by Split Banding

Definition

This is a minor repair method to arrest splits by clamping a timber section using steel bands to prevent further development of the splits by drawing the section together.

Scope of works

The repair involves the installation and tightening of steel bands around a timber member to arrest cracks, splits, or delamination.

Required materials, tools, and personnel

- i. Required material
 - Steel band
 - Bolt
 - Nuts
- ii. Required tool
 - a. For Surface Preparation
 - Wire brush
 - b. For Strapping
 - Strapping machine,
 - c. For tightening
 - Wrench
- iii. Required personnel
 - Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. Remove loose material in the vicinity of the split using a wire brush.
- ii. Using a suitable strapping machine, tension the recommended steel band into position.
- iii. Fasten the bolts and nuts on both ends of the steel band using a wrench to the recommended tension.

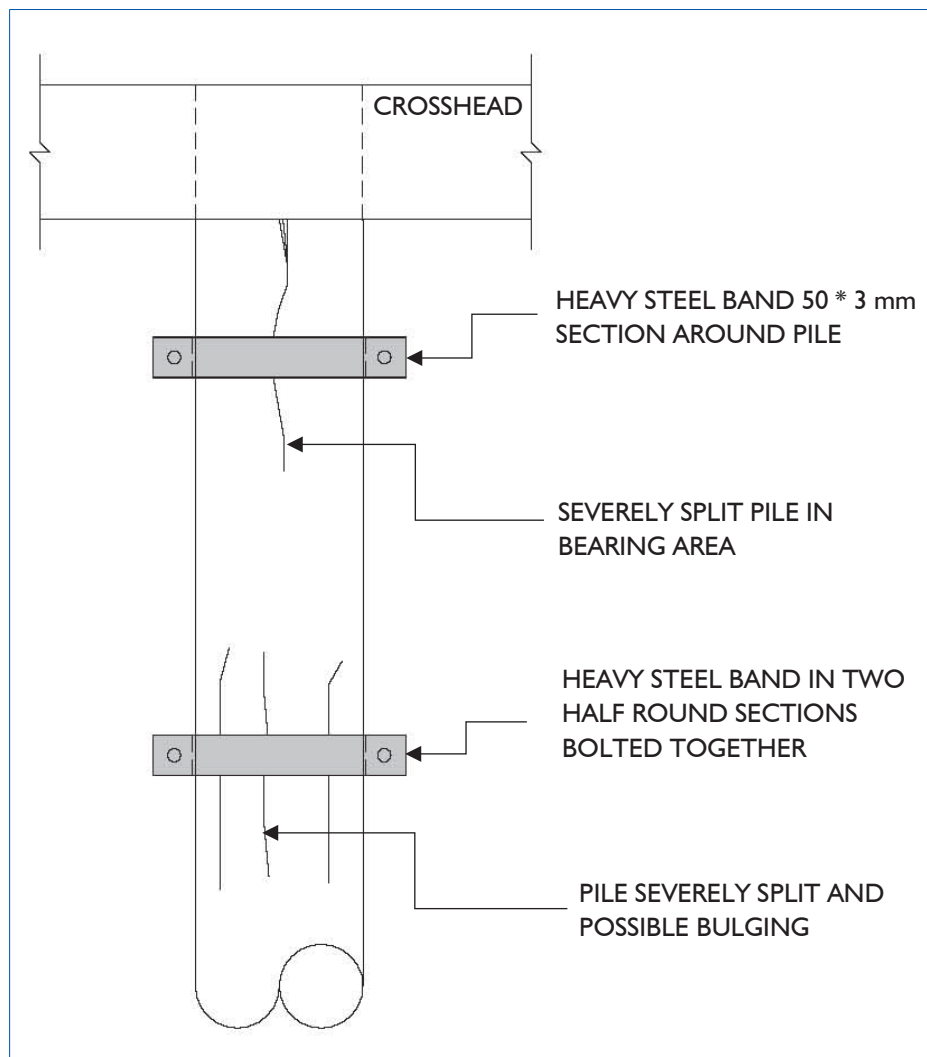


Figure 3.50 Repair of splitting timber sections by split banding

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual observation of cracks, splits and delamination as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payments

This work shall be measured by the number of steel bands instructed to be installed and fastened.

Payment shall be full compensation for the provision of all materials, tools, and labor. There will be no direct payment for the cost of storage or hauling of the steel bands and other materials to and from the bridge or bridges to be repaired.

3.3.3.2 Repair of Severely Split Timber by Anti-Split Bolt

Definition

This is a minor repair method to arrest severe splits by stitching a timber section using fasteners to prevent further development of the splits by drawing the sections together.

Scope of Works

The repair involves the installation of a series of splints to the top and bottom of the timber section along the length of the crack and draw-up bolts placed on both sides of the timber section that can be tightened between the top and bottom splints to compress and close the split.

Required materials, tools, and personnel

- i. Required material
 - Anti-split bolts
 - Nuts
 - Splints
 - Fuel
- ii. Required Tool/Equipment
 - Wrench
 - Drilling machine
 - Generator
- iii. Required personnel
 - Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

1. Drill the bolt hole and fit the selected bolt at the recommended position.
2. Remove loose material in the vicinity of the split using a wire brush.
3. Install the splints and fasten the nuts to the recommended tension using a wrench.

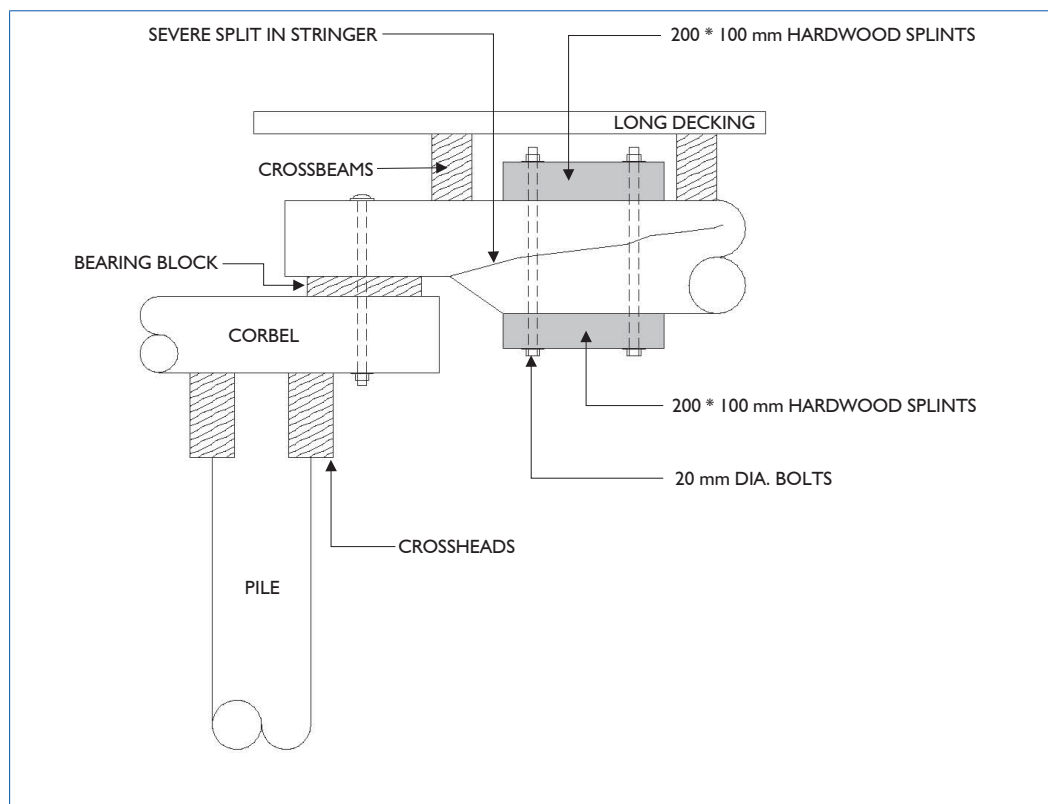


Figure 3.51 Repair of split timber with anti-split bolt

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual observation of cracks, splits and delamination as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payments

This work shall be measured by the number of fasteners instructed to be installed and fastened.

Payment shall be full compensation for the provision of all materials, tools, labor, services of the technical service advisor, and work on steel bands. There will be no direct payment for the cost of storage or hauling of the anti-split bolts and other materials to and from the bridge or bridges to be repaired:

3.3.3.3 Repairing Splitting Timber Stringer

Definition

Timber stringers consist of parallel lines of wooden beams laid over the piers and abutments in single or multiple-span bridges.

Stringer bridges can be identified by the full sawn timber stringers or girders placed in the longitudinal direction of the bridge with a transverse timber deck laid and attached to the top of the stringers.

The outside stringer on a timber bridge is more susceptible to deterioration due to its increased exposure to the elements, including rain, sunlight, and debris flow.

All dirt and loose decayed material should be removed and consideration given to adding flashing to prevent excessive wetting and further repairs if checks or splits are present.

Timber stringers suffering from severe splitting and excessive pipe rot should be replaced or supplemented.

Scope of Works

A new timber stringer or preferably a steel beam can be placed alongside the existing stringer to reduce the load it is required to carry.

Care must be taken in locating the new beam so that it does not result in the application of loads to the cantilevered portion at the end of the timber crosshead and cause failure of the crosshead. If the new beam is placed between piles, the condition of the crosshead should be assessed to ensure a shear failure does not occur, especially if the timber is short grained red gum.

An additional crosshead or other strengthening may be required.

The new beam should be placed on the span and hoisted into place through holes in the deck at each support. The new beam should be pulled tightly against the crossbeams and packed at the supports, with bolting arranged to hold the beam firmly in place.

Required Materials, Tools/Equipment and Personnel

i. Required materials

- Galvanized threaded rods or lag bolts
- Steel channels, plates, or angles

ii. Required Tools/ Equipment

- Torque wrench
- Awl
- Drill

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

1. Identify the area and extent of deterioration using awls and/or other non-destructive methods.
2. Using the steel elements that have been properly sized for the desired added strength and also for the recommended minimum extension of 600mm to either side of the deterioration extents, center the elements on the area of deterioration.
3. Attach the pre-drilled elements to the stringer using threaded rods extending through the stringer and elements on each side or individually using lag bolts. Pattern the rods or bolts per the designed layout. Additional holes for drainage in any members fastened to the bottom should be provided.

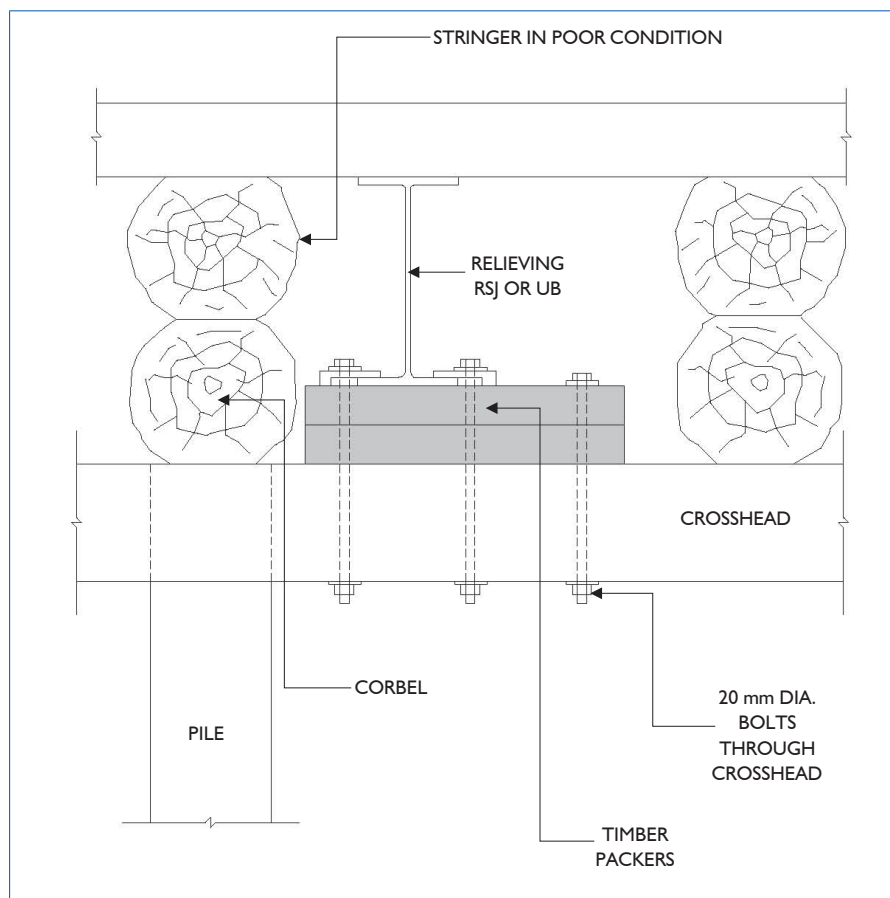


Figure 3.52 Repair of splitting timber stringer

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual observation of cracks, splits and delamination as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payment

Measurement shall be in number of timber stringers installed.

Payment shall include full compensation for provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.3.3.4 Repairing Split and Rotten Corbels

Definition

A corbel is a short timber member used at piers to help support the ends of timber girders. Timber corbels subjected to weathering will split and rot despite the application of petroleum jelly to seal the exposed end grain of the wood. With drying, the splits become longer and wider. Without end treatment the timber is susceptible to insect or fungal attack and timber corbels eventually fail by crushing or collapse as a result of loss of section due to piping, commonly combined with severe longitudinal splitting.

Scope of Works

Repairs should be implemented before the splitting or end pipe rot become excessive to avoid crushing or disintegration of the corbels.

Corbels that are badly deteriorated due to splitting, pipe rot or crushing should be replaced.

Required Materials, Tools/Equipment and Personnel

i. Required materials

- Lag bolts
- Fuel
- Petroleum jelly
- Circular nail plate

ii. Required Tools/ Equipment

- Drill
- Spanner
- Torque wrench
- Generator
- Scaffold/lift

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. Horizontal holes are drilled through the corbels near each end and 20 mm diameter anti-split bolts and large size washers are installed to prevent further splitting of the ends.
- ii. The end grain can be treated with a preservative or at least sealed with hot petroleum jelly to reduce weathering.

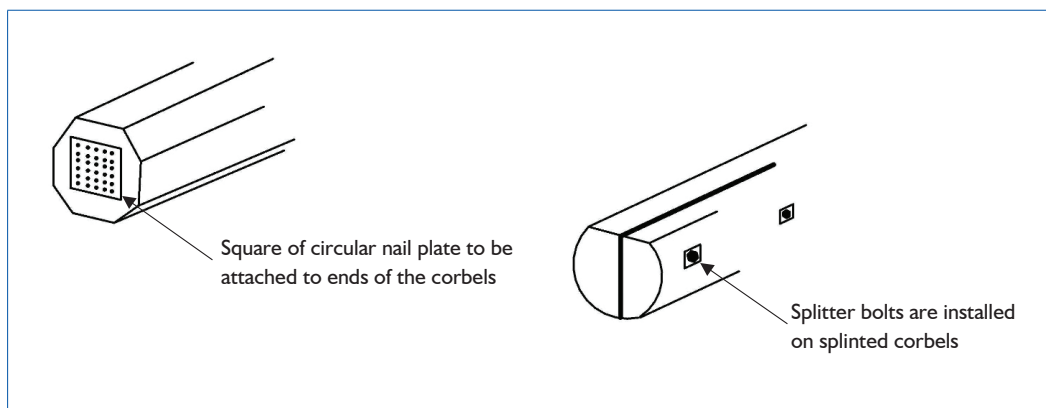


Figure 3.53 Repairing timber corbels

- iii. If the corbels have timber bearing blocks under the stringers, it is possible to band the ends of the corbels which is more effective than anti-split bolting.

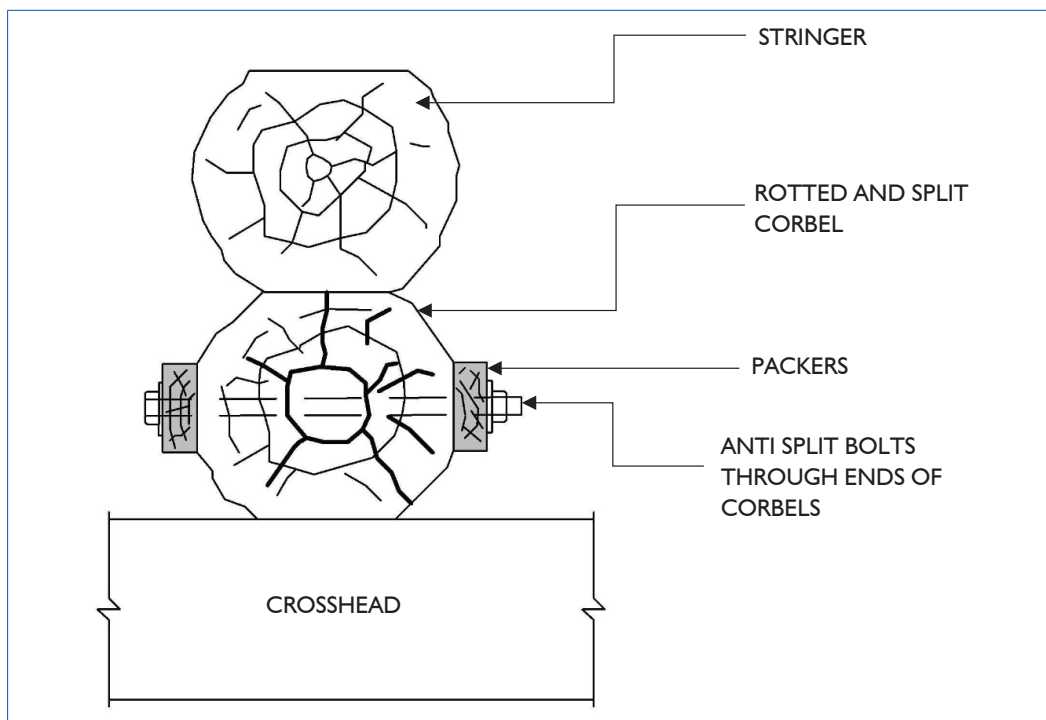


Figure 3.54 Repair of split and rotted corbels

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Visual observation of cracks, splits and delamination as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payment

Measurement shall be in number (No.) of corbels installed.

Payment shall include full compensation for provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.3.3.5 Replacing Severely Split Spiking Planks

Definition

Spiking planks can be used on timber bridges to connect the cross decking to the timber stringers without causing spike damage to the stringers. They are also used to spike timber cross decking to steel beams.

Scope of Works

The decking is spiked down at the outer girders only onto sacrificial spiking planks with no connection to the inner girders to reduce spike induced cracking of the girders.

Required Materials, Tools/Equipment and Personnel

i. Required materials

- Timber
- Nails

ii. Required tools/equipment

- Hand Saws
- Hammer

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- Spikes requiring replacement and any split and rotted portions of spike plank should be removed, simultaneously, new planks should be hammered into position.
- The new plank eventually replaces the old, by juggling the two operations.
- This operation is performed best whilst the bridge is temporarily closed for the duration of the works.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual observation of cross heads and timber end terminations as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payment

Measurement shall be in linear meters (m).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for timber of rotting and splitting as detailed in plans and specifications.

3.3.3.6 Replacing Timber Crosshead/Cap Wales/Half Caps

Definition

The primary function of a crosshead is to transfer vertical and longitudinal loads from the girders and corbels to substructure piles. They also act in conjunction with the diagonal bracing and wales to distribute horizontal loads such as wind and debris forces through the substructure.

The weathering in the crosshead is commonly the result of moisture penetration from the ends or the surface of the member. Typical deterioration in a crosshead includes splitting, edge rot and end rot or a failure of the crosshead due to excessive load applied between pile supports.

Scope of Works

Replacing Timber Crosshead/Cap Wales/ Half Caps involves the replacement with either a new timber crosshead or a steel channel crosshead. If only one end of the crosshead is defective it may be sufficient to add a new steel channel over the damaged length rather than replace the whole crosshead.

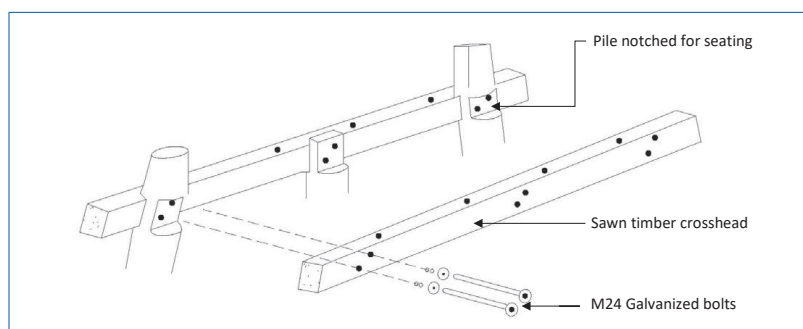


Figure 3.55 Additional timber crosshead

Required Materials, Tools/Equipment and Personnel

i. Required materials

- Water proofing agent
- Bolts/lock nuts and washers
- Grease
- Bituminous felt
- New cross head planks
- Nails
- Fuel

ii. Required tools/equipment

- Brush
- Hammer
- Spanners
- Wood saw
- Wood plane
- Drill
- Generator

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. Inspect the crosshead to identify damage due to weathering and treat the crosshead by repairing or replacing it.
- ii. Recoat with a suitable waterproofing agent as necessary after brush coating a diffusing preservative over all repairs.
- iii. The pile attachment bolts should also be checked for tightness to prevent differential movement between crosshead and pile. Tighten or replace bolts as necessary.
- iv. If the crosshead has signs of severe splitting, edge rot or end rot it should be replaced.
- v. Prop the girders to relieve loads on the crosshead. The advice of a structural engineer should be sought with the design of the temporary prop. Particular

attention should be given to bracing the props to prevent slippage, especially if traffic is permitted to continue using the bridge while it is being repaired. In general, it is considered safer to close the bridge if possible, during crosshead replacement.

- vi. The girders beams should then be raised slightly to allow bolting to be released and the defective crosshead removed.
- vii. The new predrilled crosshead section is lifted and slipped into position and drilled and the bolts coated with grease and retightened. The new crosshead should bear on the pile notch, or steel packers installed to provide direct bearing support. All contact surfaces should be treated with a preservative and grease, and a bituminous felt placed in the interface.
- viii. The props are then removed transferring the support of the girders back to the crosshead.

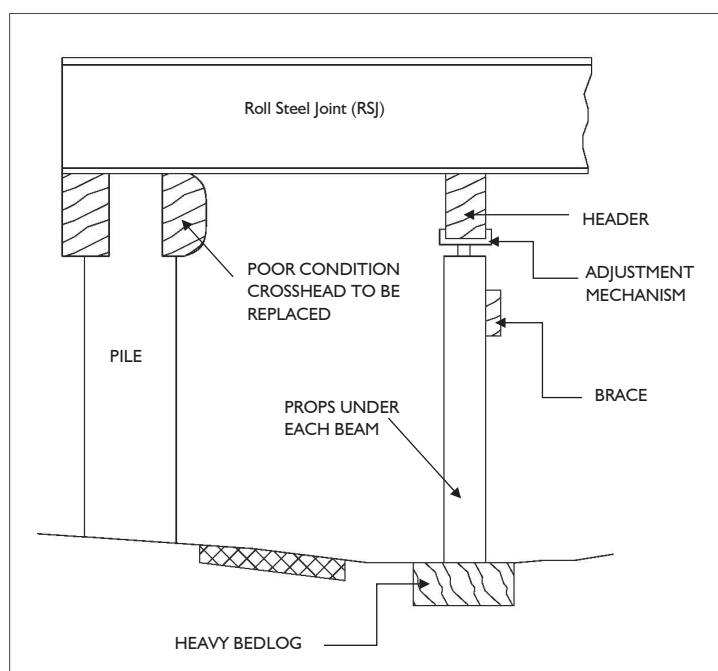


Figure 3.56 Replacement of timber crosshead

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual observation of cross heads and timber end terminations as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be based on linear meter (m) for replaced crosshead/cap wales / half cap

Payment shall include full compensation for the replaced crosshead/cap wales /half cap, provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.3.3.7 Repairing Timber Deck

Definition

This involves the repair of a deteriorated timber deck commonly as a result of poor drainage and general weathering.

Scope of Works

Timber decks should be checked for loose connections, dampness, decay, splitting, crushing, fastener failure, and wear. Particular attention should be paid to locations where timber decking rests on other members and it is more likely to be damp for extended periods.

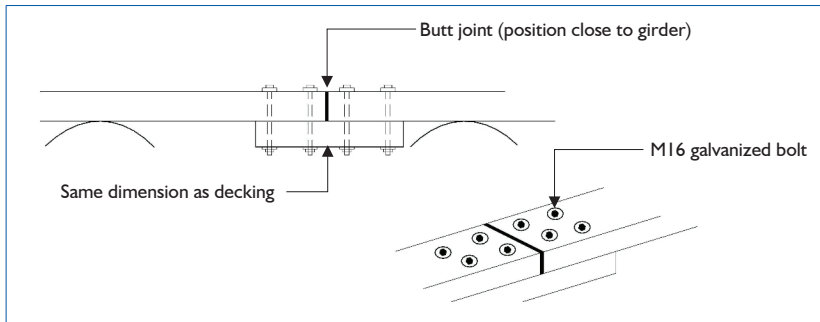


Figure 3.57 Repair of timber deck

Required Materials, Tools/Equipment and Personnel

i. Required materials

- New deck planks
- Bolts/lock nuts and washers
- Nails
- Fuel

ii. Required tools/equipment

- Hammer
- spanners
- Wood saw
- Wood plane
- Lifting jerks
- Drill
- Generator

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. Remove wearing surface and any running planks over the defective area.
- ii. Release bolts and lift kerbs, where required.
- iii. Check the decking planks for defects.
- iv. For loose decking planks that are in reasonable condition tightening of bolts and replacement of nails may be all that is required. The bolts should be retightened against stiff steel angle cleats which will not bend as the bolt is tightened.
- v. If the area around the bolt hole is damaged then larger, heavier washers can be used to distribute the fixing load to a larger area. Heavy spring washers, lock nuts or nylon lock nuts can be used to prevent loosening of the fastener.
- vi. If deck planks are badly rotted, they should be replaced.
- vii. Existing gaps between planks should be noted and maintained as these gaps provide air circulation and allow timber to dry out after rain.
- viii. Cut out defective planks and remove bolts, cut off where required.
- ix. Planks should be bolted to angle cleats at their ends and at intermediate crossbeams to hold them tightly in place and to prevent lifting under load.
- x. Replace & reinstate bolt-on kerbs as required.
- xi. Reinstate wearing surface.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual observation of loose connections, general dampness decays, splits and crushing as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be based on square meter (m²) for repaired deck.

Payment shall include full compensation for the repaired timber deck, provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.3.3.8 Repairing Timber Kerbs

Definition

This item defines kerbs that are constructed of timber which form an upstand at the edge of bridge. Kerbs may be formed from either hardwood or plywood construction.

If the timber kerbs are in poor condition due to severe weathering, rot and splitting, kerb

connections could be loose, and the kerb may be leaning. If the kerb is in poor condition, the posts may also be loose and have limited capacity to resist road vehicle impact.

Timber kerbs serve a number of functions on timber bridges:

- (1) The main purpose is to act as a containment device for vehicle wheels, generally in conjunction with a timber or steel barrier. The kerb also provides an attachment point for the associated posts.
- (2) The kerb also helps to firmly tie down the outer ends of transverse deck planks where the kerb is located above the outer girder.

Particularly on bridges with timber rails, the kerb is probably providing greater containment capacity than the railing system itself.

Scope of Works

The most common form of timber kerb consists of two hardwood members assembled to form a 200 x 200mm section. This helps ease component supply and also simplifies formation of scuppers.

An alternative form of kerb fabricated from plywood is being successfully used and has the advantage of straightness and long lengths.

Required Materials, Tools/Equipment & Personnel

i. Required materials

- Timber Kerbs
- Lag bolts or threaded rods
- Galvanized M20 replacement bolts
- Chemical timber surface preservatives
- Waterproofing agents
- CN emulsion/timber oil or thick preservative grease
- Bituminous felt
- Paint
- Fuel

ii. Required tools/equipment

- Brush
- Screw drivers
- Drilling machine
- Circular saw
- Awl
- Rotary hammer
- Scaffolds
- Aerial lifts
- Air compressor and tools
- Generator

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Routine Maintenance

- i. Routine or preventive maintenance actions for timber kerbs will generally be identified and carried out during Level 1 bridge inspections. These activities would be:
 - Tightening or replacing kerb hold down bolts.
 - Application of surface preservatives or waterproofing agents.
- ii. The kerb attachment bolts should be checked for tightness as any looseness will reduce wheel impact resistance, barrier post connection effectiveness, and possibly allow decking movements.
- iii. Where corrosion of bolts is evident, they should be withdrawn and replaced by galvanized bolts of the same diameter if loss of section is evident. The bolt holes through the kerbs should be coated/packed with CN emulsion or thick grease before bolt insertion.
- iv. Where areas of decay or cracking are noted, these areas should be coated with a chemical timber preservative.
- v. Where any active termite presence is detected during these operations, treatment shall be programmed as soon as practical.

Programmed Maintenance:

- i. Where a kerb member has deteriorated to Condition State 4, its adequacy to withstand impact or to hold barrier posts will be compromised and it should be replaced. This will normally be accomplished by a full-length member in hardwood with suggested nominal gaps of 5 mm at the pier butt joins (actual gap is not critical).
- ii. Unless a full bridge length of kerbing is being replaced, the cross section of the new member shall correspond to that being replaced. To maintain the line of the kerb faces, a maximum deviation of + 10mm measured by a string line on the inside face should be achieved.
- iii. Because plywood kerbs will generally be of non-standard size, they would normally only be used or full bridge length replacement.

- iv. The junction region of the kerb and decking is an area of very high decay potential, requiring particular attention. Timber decking should be dressed in the contact area to reduce high spots and allow the kerb to be pulled down tight.
- v. All contact surfaces should be treated with a preservative and preservative grease applied. In order to remove any remaining air gaps, a bituminous felt should also be laid over the contact area. (Where a kerb is formed from 2 layers of hardwood timber, the internal contact area shall be similarly treated). The end grain of kerb timbers shall be treated before assembly because of small end gaps.
- vi. When ply kerbs are used, any faces showing veneer glue lines shall be treated with sealant in order to prevent drying out and opening up due to weather exposure. Painting of the kerb may satisfy this requirement.
- vii. Existing kerb attachment bolts may be used for the new kerb, unless corrosion of the bolts has occurred in which case galvanized M20 replacement bolts shall be used.
- viii. All bolt holes through kerbs should be treated with a preservative and a grease or petroleum jelly applied to the bolt shank before insertion in order to improve water tightness.
- ix. On bridges up to 8 m width, the kerbs should be painted white in order to provide enhanced protection to the timber and also extra delineation for traffic. For wider bridges, painting may still be considered in order to improve member durability.
- x. Consideration may be given to providing light metal spouts at scuppers to shed water away from decking ends.

Repair Method

- i. If the timber kerbs are loose but in good condition, then the bolts should be retightened and additional bolts installed as required.
- ii. If the kerbs are badly decayed, then they should be replaced.
- iii. The deck drainage adjacent to the replaced kerbs should be inspected, cleaned, rectified as required.

Monitoring and Evaluation

Monitoring and evaluation of replaced or repaired timber kerb section by the Engineer.

Performance Test - Bolt strength tests and watertightness of the jointing as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and payments

Measurement shall be in linear meters (m) of the span of timber kerbs repaired.

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for repairing of timber kerbs as detailed in plans and specifications.

3.3.3.9 Replacing Timber Corbels

Definition

A corbel is a projecting wall member used as a support for some elements of the superstructure.

Corbels that are badly deteriorated due to splitting, pipe rot or crushing should be replaced.

Scope of Works

Replacing timber corbels involves:

- Drilling & injecting termicide poison into timber (also adjacent areas),
- Application of chemical preservative to timber,
- Application of preservative grease to corbel ends,
- Application of chemical preservative to timber,
- Strengthening of corbel,
- Tightening of existing bolts or replace or install bolts,
- Replacement of timber corbel & drill & inject termicide poison into adjacent timber (girders & headstocks).

Performance deteriorates greatly as the snipe depth exceeds 30%. Corbels can be strengthened with steel brackets bolted to each side of the corbel. As the corbel hogs under applied loads, the bending moment is transferred to the stiff steel C channel brackets.

This can help prevent excessive deflection, while ensuring that bending stresses developed over the shallow midpoint of the corbel do not exceed the capacity of the timber.

Required Materials, Tools/Equipment & Personnel

i. Required materials

- Timber kerbs
- Galvanized M20 replacement bolts
- Chemical timber surface preservatives
- Waterproofing agents
- CN Emulsion or thick preservative grease
- Bituminous felt
- White paint

ii. Required tools/equipment

- Cordless drill
- A pry bar
- A flat and heavy scraping blade
- A reciprocating saw
- Screw drivers
- Drilling machine
- Circular saw

- Awl
 - Rotary hammer
 - Scaffolds
 - Aerial lifts
 - Air compressor and tools
- iii. **Required personnel**
Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. Replacing the corbel is difficult as the stringers in both spans require jacking and temporary support. The advice of a structural engineer should be sought with the design of the temporary support system.
- ii. Once the spans are propped, the bolts can be cut and the defective corbel removed.
- iii. A new corbel of the same size is then winched into place through holes in the deck each side of the support.
- iv. After fixing the new corbel to the crossheads, the stringers are lowered and new bolts
- v. Installed to fix them to the corbels.
- vi. This operation is best undertaken with the bridge closed to traffic.

Table 3.31 Repair methodology to use on timber bridges

Defect	Activities
Bolts slightly loose.	Tighten existing bolts.
Minor termite attack (active).	Drill & inject termicide poison into timber (also adjacent areas).
Minor surface decay. (May also be pipe rot up to 20% of diameter). End preservative treatment ineffective.	Apply chemical preservative to timber. Apply preservative grease to corbel ends.
Moderate surface decay. There may be pipe rot over 20% and up to 35% diameter.	Apply chemical preservative to timber.
Moderate splits or checks.	Strengthen corbel.
Bolts loose, corbel rocking under load.	Tighten existing bolts or replace or install bolts.

Defect	Activities
Heavy surface decay (marked effect on strength).	Replace timber corbel.
Heavy splitting (marked effect on strength).	Replace timber corbel.
Heavy termite attack (marked effect on strength).	Replace timber corbel & drill & inject termicide poison into adjacent timber (girders & headstocks).
Pipe rot over 35% and possibly in excess of 50% diameter loss.	Replace timber corbel.
Bolts very loose, corbel rocking under load and bolts may be corroded.	Tighten existing bolts or replace or install bolts.

Monitoring and Evaluation

Monitoring and evaluation of replaced or repaired timber kerb section by the Engineer.

Performance Test - Visual observation of loose connections, general dampness decays, splits and crushing as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and payments

Measurement shall be in Lump Sum (LS) for the length of the replaced timber corbels.

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for Replacing Timber Corbels as detailed in plans and specifications.

3.3.3.10 Installation of Flashing

Definition

This is the installation of flashing in timber bridges to ensure that vulnerable areas are adequately protected from water infiltration and related damage.



Figure 3.58 Photo of installed flashings

Scope of Works

Flashing is a crucial component in the construction of timber bridges, as it helps to prevent water infiltration and moisture-related damage to the structure. Proper installation of flashing is essential to ensure the durability and longevity of the bridge.

Conduct a thorough assessment of the bridge to identify areas vulnerable to water infiltration, such as joints, intersections, and areas close to the ground. Develop a detailed plan specifying the type of flashing material, placement locations, dimensions, and installation techniques.

Required Materials, Tools/Equipment & Personnel

i. Required materials

- Water proof membranes (aluminium, copper, galvanized steel)
- Self-tapping screws
- Nails

ii. Required tools/equipment

- Generator
- Saw
- Rotary hammer
- Screw gun
- Hammer

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. Prepare the surface

Clean and prepare the timber surfaces where the flashing will be installed, ensuring they are clean, dry, and free of debris.

ii. Select flashing material

Choose an appropriate flashing material based on the bridge design, location, and environmental conditions. Common options include metal (e.g., aluminium, copper, galvanized steel) or flexible waterproof membranes.

iii. **Cut and shape the flashing**

Cut the flashing material into the required lengths and shapes based on the dimensions and layout of the bridge components.

iv. **Install base flashing**

Begin by installing base flashing at the base of vertical timber components to create a watertight seal.

Attach the base flashing using appropriate fasteners, ensuring a secure and stable connection.

v. **Install step flashing**

Install step flashing at junctions between horizontal and vertical timber components to direct water away from vulnerable areas.

Secure the step flashing using fasteners, ensuring a snug fit against the timber.

vi. **Overlap and secure flashing**

Ensure that the flashing pieces overlap each other to create a continuous barrier against water infiltration.

Secure the flashing in place using appropriate fasteners, ensuring a tight seal and preventing water penetration.

vii. **Seal joints and seams**

Apply compatible sealants or waterproofing materials to all joints, seams, and fastener penetrations to further enhance water resistance.

Ensure the sealants are applied evenly and cover all potential points of water entry.

viii. **Inspect and test**

Conduct thorough inspections to verify the integrity of the flashing installation, ensuring proper alignment, secure attachment, and effective sealing.

Perform water tests to validate that the flashing system effectively redirects water away from vulnerable areas.

ix. **Complete installation**

Once the flashing is securely in place and tested for water tightness, complete any remaining construction or finishing work on the bridge.

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual observation of loose coverings and camber checks as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be in square meters (m²) calculated as the area instructed by the Engineer or as shall be measured by the Engineer.

Payment shall be full compensation for the provision of all materials, tools, and labor.

3.3.4 Major Repair Methods in Masonry Bridges

Major repair methods in masonry bridges are: repointing stonework, replacing stonework, repair of split or cracked blocks or mortar, repair of bulging sidewall (spandrel wall), stabilising abutment or wing wall movement and repair of arch cracking.

The defects addressed in this section of the manual are listed in Table 3.32.

Table 3.32 Defects addressed in major repairs to masonry bridges

Classification	Repair/Strengthening Method	Method	Defects Addressed
Major Repairs	Repair	Repointing stonework and replacing stonework	Loss of mortar Sectional loss Crack Water leakage
	Repair	Repair of split or cracked blocks or mortar	Crack/Split masonry Missing masonry sections
	Repair	Repair of bulging sidewall (spandrel wall)	Deformation/ Displacement of masonry blocks
	Repair/Preventive	Stabilising abutment or wing wall movement	Abnormal alignment (Plan/Profile)
	Repair	Repair to arch cracking	Crack
	Repair	Replacement of member (Section 3.4)	Abnormal deflection Inclination Abnormal alignment

3.3.4.1 Repointing Stonework and Replacing Stonework

Definition

This is the restoration of old mortar and/ or bricks that have lost their structural integrity.

The mortar between the masonry stones deteriorates with time due to weathering, water wash and moisture penetration from the fill behind the walls. When the depth of mortar loss reaches 20mm, repointing of the stonework is required. When depth of mortar loss exceeds 20mm, stone movement or crushing of the remaining mortar can result leading to slippage of stones in arches or dislodgement of stones in walls.

In some cases where aesthetics is not a concern, blocks can be replaced with concrete or stiff mortar mix. Care must be taken to ensure that the concrete does not slump or shrink away from the surrounding stones.



Figure 3.59 Missing block

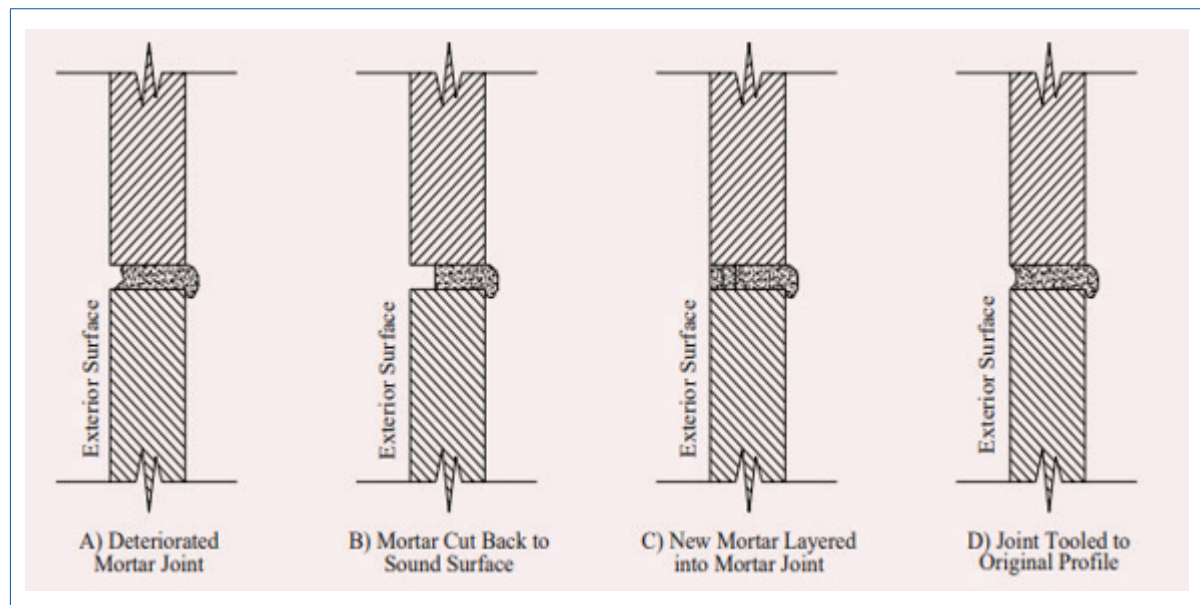


Figure 3.60 Repointing stonework

Scope of Works

This repair method involves removal of old mortar and bricks that have lost their integrity.

Required Materials, Tools/Equipment and Personnel

- i. **Required materials**
 - Ordinary Portland Cement
 - Fine aggregate
 - Clean water
- ii. **Required tools/equipment**
 - Chisel
 - Wire brush
 - Small hammer
 - Mortar mix bucket
 - Safety goggles
 - Trowel
 - Scaffolding or inspection vehicle
- iii. **Required personnel**
 - Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. **Remove old mortar**

Cut out the old mortar being careful not to damage the nearby units or to remove too much mortar at one time. Generally, the depth of cut should not exceed 20mm, or until sound mortar is reached.
- ii. **Select the proper mortar type**

As much as possible, try to closely match the mortar used in the original construction. In general, softer mortars with more lime than typical mortars serve as a more effective tuck-pointing mortar.
- iii. **Pre-hydrate the mortar**

Mix the mortar using as little water as possible and allow the mix to hydrate for one hour prior to repointing. Using a stiff mortar will reduce the plastic shrinkage.

iv. **Place new mortar**

Force new mortar into the joint in layers not exceeding 6 mm. Each layer should be thump tamped hard before subsequent layers are applied.

Where the mortar loss is deeper than 20 mm it should be replaced with a low-pressure injection of 1:3 lime/cement:sand mix to reach the rear of the stones and backfilled to depth of 10 mm from the front face of the stone.

v. **Finish tooling**

Once the mortar has sufficiently set, tool the mortar to match the original mortar.

vi. **Curing**

Moist curing should be provided for a minimum of 7 days to prevent shrinkage cracking. The stonework should be wetted or watered three times a day.

vii. **Quality control**

All works shall be done to specification and as approved by the Engineer.

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual inspection, consistency test, abrasion resistance and chemical resistance as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be square meters (m²) calculated as the area instructed by the Engineer.

Payment shall include full compensation for the removal of old mortar and/or deteriorated bricks, surface cleaning and preparation, furnishing and placing of all materials, labour, equipment, tools, as well as construction and removal of formworks and other temporary works necessary to complete the repointing stonework and replacing stonework.

3.3.4.2 Repair of Split or Cracked Blocks or Mortar

Definition

This repair method involves restoration of split or cracked masonry.

The causes of cracking in masonry include differential settlement of foundations, thermal movement, growth of brickwork, corrosion of embedded iron or steel, impact damage and growth of vegetation in or around the brickwork.

Prior to undertaking repair of extensive cracking in masonry, the cause of the cracking should first be determined along with an assessment of what further deterioration is likely. The advice of a structural engineer should be sought in making this assessment. In addition, there should be an assessment of the significance of the existing and anticipated cracking for the load carrying capacity of the structure.

Particular care should be exercised in cases where the crack formation is comparatively recent if the cracks are live (i.e., crack width fluctuates) or the crack is seen as posing a threat to the stability of the structure.

If the cracks are known to have existed for some time without change, they may not be a source of serious concern though steps should be taken to repair them. Cracks that have formed due to overload tend to close after the overload is removed and may therefore not require treatment.

Masonry arches, abutments, retaining walls, and wing walls are vulnerable to cracking due to differential settlement of the foundations. Factors affecting the stability of a masonry arch bridge include the following:

- Differential settlement within an abutment or pier may cause longitudinal cracks along an arch ring, indicating that the arch has divided into separate rings.
- Movement or settlement of the foundations of an abutment or pier may cause lateral cracks across an arch ring and settlement in the roadway, indicating that the arch has broken up into separate segments.
- The settlement at one end of an abutment or pier may cause diagonal cracks starting near the edge of the arch at the springing and extending to the centre of the arch at the crown.
- Increased flexibility of the arch ring may cause cracks in the spandrel walls near the quarter points.
- Outward movement of the spandrel walls due to the lateral pressure of the fill, particularly in cases where the traffic can travel close to the parapet may cause longitudinal cracking near the edge of the arch.
- Lateral movement of the wing walls may cause cracking and, if adjacent to the roadway, damage to the road surface.



Figure 3.61 Cracks at sidewall and loss of mortar between bricks

Scope of Work

Crack repair involves removing the existing defective mortar, cleaning with compressed air then pressure injecting a cement/lime:sand mortar mix into the crack to ensure it

is fully sealed, and that full bonding to the sides of the crack has been achieved. The appropriate mixture is a 1:3 mix though as a general rule the mix should be softer and more permeable than the stonework.

Depending on the extent of the cracking, various intervention options may be employed:

1. Sealing of cracks by epoxy resin injection.
2. Repairing brickwork with epoxy mortar.
3. Installing ferro-cement plate at the corner (95% cement mortar mix and 5% wire mesh).
4. Rebuilding portion of a wall.
5. Stitching method of repairing cracks.

Required Materials, Tools/Equipment and Personnel

i. Required materials

- Ordinary Portland Cement
- Rebars
- Fine aggregate
- Epoxy Sealant
- Clean water

ii. Required tools/equipment

- Chisel
- Cutting disk
- Raking rod
- Wire brush
- Small hammer
- Mortar mix bucket
- Safety goggles
- Trowel
- Air Compressor
- Mortar pressure pump
- Scaffolding or inspection vehicle

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. Remove defective mortar: Cut out the defective mortar in small bits being careful not to damage the nearby units. Generally, the depth of cut should not exceed 20mm, or until sound mortar is reached.
- ii. Clean with compressed air.
- iii. Wet the prepared area using clean water.
- iv. Pressure-inject cement/sand mortar mix into the crack to ensure it is fully sealed, and that full bonding to the sides of the crack has been achieved. The appropriate mixture is a 1:3 mix though as a general rule the mix should be softer and more permeable than the stonework.
- v. Moist curing should be provided for a minimum of 7 days to prevent shrinkage cracking. The stonework should be wetted or watered three times a day.
- vi. Low-pressure silicone sealant may be injected on small cracks which are not progressive.
- vii. All works to be done to specification and as approved by the Engineer.



Figure 3.62 Crack repair

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual inspection, consistency test, abrasion resistance and chemical resistance as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be square meters (m²) calculated as the area instructed by the Engineer.

Payment shall include full compensation for the cutting and prepare the cracks, surface cleaning and preparation, furnishing and placing of all materials, labour, equipment, tools, as well as construction and removal of formworks and other temporary works necessary to complete the repairing splits and cracks on blocks and mortar.

3.3.4.3 Repair of Bulging Sidewall (Spandrel Wall)

Definition

It occurs when side walls of masonry arch bridges bulges outwards due to a combination of moist infill and secondary compaction of the infill due to traffic loading. Thus bulging can cause cracking, loss of mortar and movement of stones relative to each other.

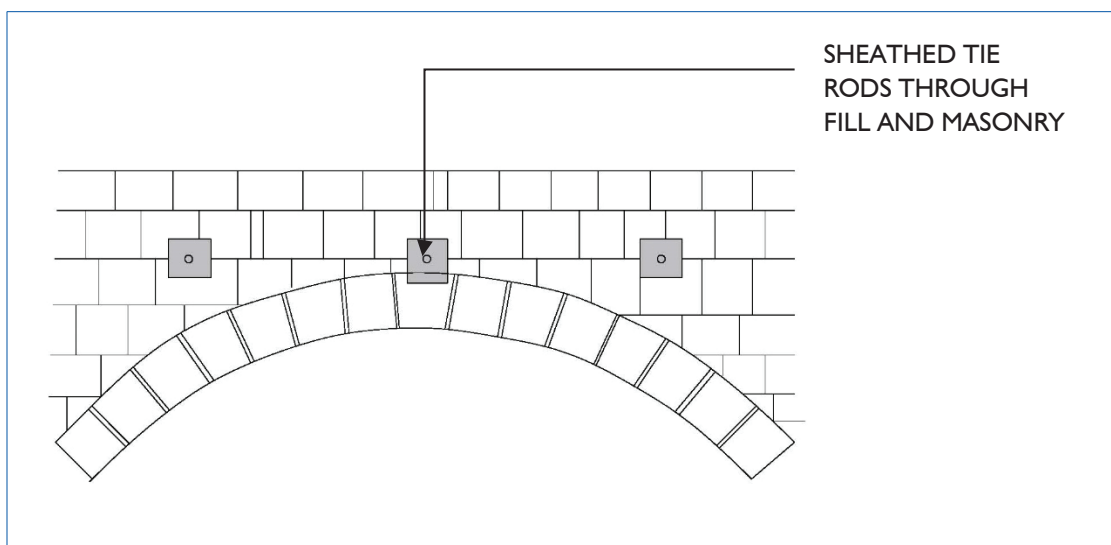


Figure 3.63 Repair to side wall (Spandrel wall)

Scope of Works

The scope of works on repair of bulging sidewalls (spandrel wall) entails identification and demarcation of the bulging side wall area, removal of bulging masonry stones, install tie rods to strengthen bulged sidewalls and infill material from one end to the other, fit anchor plates on both sides of the tie rods and hide with a thin veneer of stone, epoxy bonded to the plates to match masonry walls. After installing the tie rods in place, cracked mortar can be repaired in accordance to the procedures highlighted in Section 3.3.4.1 Repointing Stonework.

Required Materials, Tools/Equipment and Personnel

i. Required materials

- i. Ordinary Portland Cement
- ii. Fine aggregates
- iii. Clean water
- iv. Epoxy
- v. Galvanized tie rods
- vi. Plastic sheath
- vii. Metal cover plates
- viii. Masonry stone

ii. Tools and Equipment

- i. Trowel
- ii. Plumb bob
- iii. Chisel
- iv. Measuring tape
- v. Brush
- vi. Pressure injection pump
- vii. Mortar mixing bucket/tray
- viii. Low pressure injection machine
- ix. Wheelbarrow
- x. Water container
- xi. Scaffolding
- xii. Inspection vehicle
- xiii. Pre-tensioning machine
- xiv. Drill

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Works Sequence

i. To demarcate bulged sections on side wall (spandrel wall)

The repair contractor should demarcate all bulging sections on the side walls (spandrel walls), erect scaffolding/setup inspection vehicle in preparation to commence the works..

ii. Replace defective masonry stone

In case of any defective masonry stone on the side wall (spandrel wall), replace with suitable masonry stone and joint using mortar.

iii. Install tie rods across the side wall

Drill holes through the masonry wall and infill embankment before installing the pre-tensioned tie rods covered with plastic sheaths and anchor them on both ends using cover plates.

iv. Waterproofing and Drainage

Ensure proper waterproofing measures and drainage systems are in place to prevent water accumulation, which can contribute to further bulging or damage.

v. Repoint masonry using mortar

In case of cracked mortar joints between masonry stones, crack repair is recommended. This process involves removing the existing defective mortar, cleaning with compressed air then pressure injecting a cement/lime to sand mortar mix into the crack to ensure it is fully sealed, and that full bonding to the sides of the crack has been achieved. The appropriate mixture is a 1:3 mix though as a general rule the mix should be softer and more permeable than the stonework.

vi. Curing repointed masonry

All sections of the bulging side wall (spandrel wall) with repointed masonry repairs need thorough and continuous curing for a minimum of 7 days. to gain strength and to minimize drying shrinkage.

vii. Quality control

All works shall be done to specification and as approved by the Engineer.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual inspection, plumb test, as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be square meters (m²) calculated as the area instructed by the Engineer.

Payment shall include full compensation for the preparation, furnishing and placing of all materials, labour, equipment, tools, other temporary works necessary to complete the repair of the bulged sidewalls (spandrel walls).

3.3.4.4 Stabilising Abutment or Wing Wall Movement

Definition

The lateral earth pressure on a wing wall can cause the wall to move laterally or rotate thereby creating a large gap between it and the adjacent abutment walls and resulting in loss of embankment fill. On older bridges where the wing walls and the abutment walls are monolithic, severe cracking can occur at the junction between them. The wing walls should be restrained from further movement to prevent further damage.

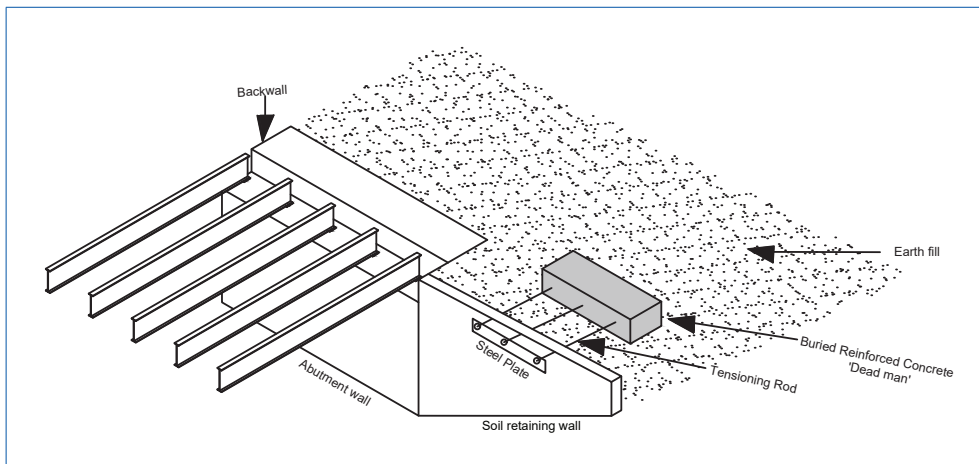


Figure 3.64 Repair to wing wall

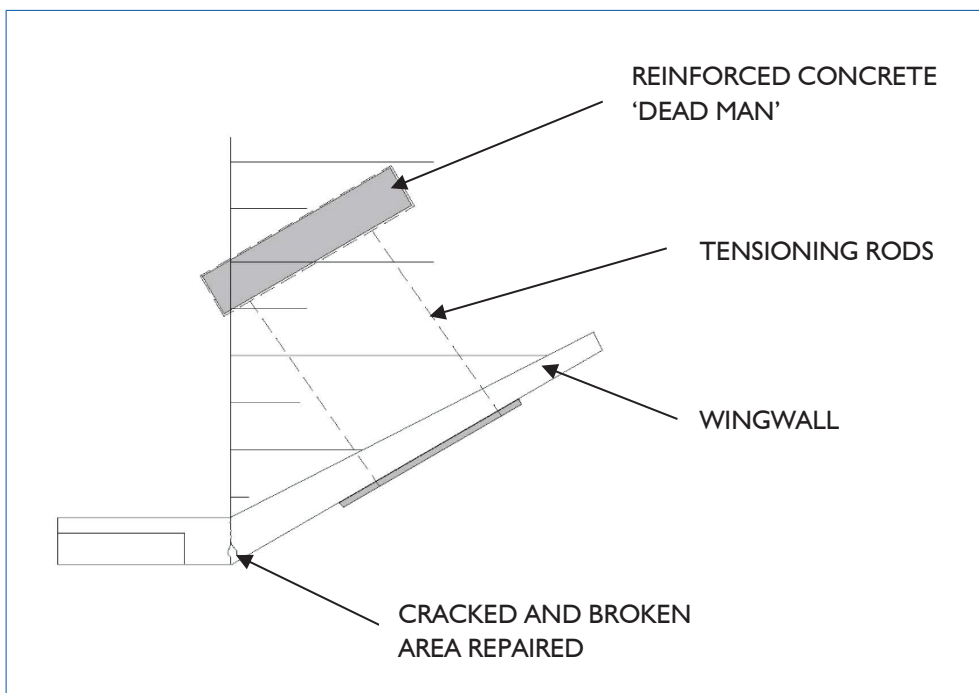


Figure 3.65 Stabilizing abutment or wing wall

Scope of Works

Repair works involve drilling/coring of holes through the wing wall, installing pre-tensioning tie rods sheathed with plastic, casting in place reinforced concrete 'dead man' into the embankment behind the wall as instructed by the Engineer, backfilling excavated area and applying epoxy grout on all cracked areas.

Required Materials, Tools/Equipment and Personnel

i. Required materials

- i. Portland cement
- ii. Fine aggregates
- iii. Clean water
- iv. Epoxy
- v. Galvanized tie rods
- vi. Plastic sheath
- vii. Metal plates
- viii. Masonry stone

ii. Required Tools and Equipment

- i. Trowel
- ii. Plumb bob
- iii. Measuring tape
- iv. Concrete/mortar mixer
- v. Concrete/mortar mixing bucket
- vi. Wheelbarrows
- vii. Concrete mixing tray/mortar mixing pan
- viii. Water container
- ix. Scaffolding
- x. Inspection vehicle
- xi. Drilling/coring machine

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Works Sequence

- i. Drill/core holes through the walls and embankment.
- ii. Excavation for the reinforced concrete counterweight 'dead man'.
- iii. Insert tensioning rods into holes and push them through the embankment. These rods should be galvanized and sheathed in plastic over the length they are within the embankment fill.
- iv. Install by fixing the tensioning rods into a reinforced concrete 'dead man' cast into an excavated hole behind the wall in the embankment as instructed by the Engineer.
- v. After installing pre-tensioning tie rods, the excavation is backfilled with compacted fill and the cracks in the walls epoxy grouted.

NB: Other solutions to the problem include 'soil nails' and helical ties that avoid the need to excavate for and cast the concrete 'dead man'.

For smaller walls it may be more appropriate to excavate behind it and drag it back into place or simply reconstruct wall and replace the backfill. The design of the replacement wall and the selection and compaction of the fill behind the wall should be such as to avoid a repeat of the wall failure.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual inspection, plumb test and consistency test as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payment

Measurement shall be based on square meters (m²).

Payment shall include full compensation for the provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.3.4.5 Repair Arch Cracking

Definition

Arch cracking in masonry bridges refers to the development of fissures within the arch structure of a masonry bridge. Arches are a common structural feature in many masonry bridges and are known for their ability to support heavy loads through the distribution of weight along the curved shape of the arch.

The arch cracks may occur as a result of settlement and movement, thermal expansion and contraction, material deterioration, loading and overloading, seismic activity, design or construction flaws.

Scope of Works

The scope of works on the damaged arch are crack repairs, repairs on spalled areas, repointing, structural reinforcement, reconstruction if necessary, surface finishing, protective coating and curing.

Required Materials, Tools/Equipment & Personnel

i. Required materials

- Masonry material (quarry stone/block/brick)
- Mortar
- Grout
- Epoxy

ii. Required tools/equipment

- Raking rod
- Trowel
- Spade
- Cold chisel
- Plumb bob and line
- Spirit level

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. Cleaning and surface preparation

Clean the arch surface, removing loose debris, dirt, or other contaminants that could hinder proper adhesion of repair materials.

Use appropriate cleaning methods, such as pressure washing, to prepare the surface.

ii. Structural reinforcement

Reinforce the arch as needed using suitable methods, such as installing steel rods or mesh, to enhance structural integrity.

iii. Crack repair

For cracks:

- Rout out and widen cracks to provide a better bonding surface for the repair material.
- Apply a bonding agent to the cleaned and prepared surface to enhance adhesion.

- Fill the cracks with an appropriate repair material, such as epoxy, grout, or mortar, ensuring the material penetrates and fills the crack completely.

iv. **Spall repair**

If there is spalling (flaking or chipping) of the masonry:

- Remove loose or damaged material using suitable tools like a chisel or grinder.
- Apply a bonding agent to the prepared surface.
- Fill the spalled areas with a suitable repair mortar or concrete mix, matching the color and texture of the original arch.

v. **Repointing**

Repoint any deteriorated or damaged mortar joints with fresh mortar, ensuring a strong and uniform bond.

vi. **viii. Surface finishing**

Match the original finish and appearance of the arch by applying appropriate finishes, textures, or coatings.

vii. **Protective coatings**

Apply protective coatings to the repaired arch to enhance durability, water resistance, and resistance to environmental elements.

viii. **Curing**

Allow the repair material to cure according to the manufacturer's instructions, ensuring proper strength and durability.

ix. **Reconstruction (if necessary)**

If the damage is severe, reconstruction of sections of the arch may be necessary. This could involve carefully removing and replacing the damaged masonry while maintaining the original design and appearance.

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual inspection, crack test and spalling test as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be in square meters (m²) calculated as the area instructed by the Engineer or as shall be measured by the Engineer.

Payment shall include full compensation for the provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.3.5 Major Repair Methods in Bridge Expansion Joints

Major repair methods carried out to expansion joints are; repair of asphaltic plug joint and replacement of expansion joint.

The defects addressed in this section of the manual are listed in Table 3.33.

Table 3.33 Defects addressed in major repairs to bridge expansion joints

Classification	Repair/Strengthening Method	Method	Defects Addressed
Major Repairs	Repair	Repair to asphaltic plug joint	Water leakage Abnormal space/noise Difference in elevation Deteriorated sealant
	Repair	Replacement of expansion joint	Water leakage Abnormal space/noise Difference in elevation Deteriorated sealant Cracking on primary members Rupture/peeling off of rubber seal

3.3.5.1 Asphaltic Plug Joint

Definition

The quality of expansion joints is vital to the behaviour of the bridge and its durability. They need to be maintained by waterproofing and ensuring resistance to leakage. The most common joint sealant is asphalt which is easily damaged by repeated traffic load and aging.

The usual gap between concrete edges is around 20 mm considering a mean temperature of 27°C and a range of $\pm 10^\circ\text{C}$ in Kenya. The movement of a 20 m bridge span due to changes in temperature is $12 \times 10^{-6} / ^\circ\text{C} \times 20 \text{ m} \times (\pm 10^\circ\text{C}) = \pm 2.4 \text{ mm}$ and the movement of the same span due to traffic load is approximately less than 5 mm. Total movement of a 20 m span of a reinforced concrete bridge deck is below $\pm 10 \text{ mm}$.

With these considerations, the most suitable repair measure for damaged asphalt sealant is the installation of asphaltic plug joint.

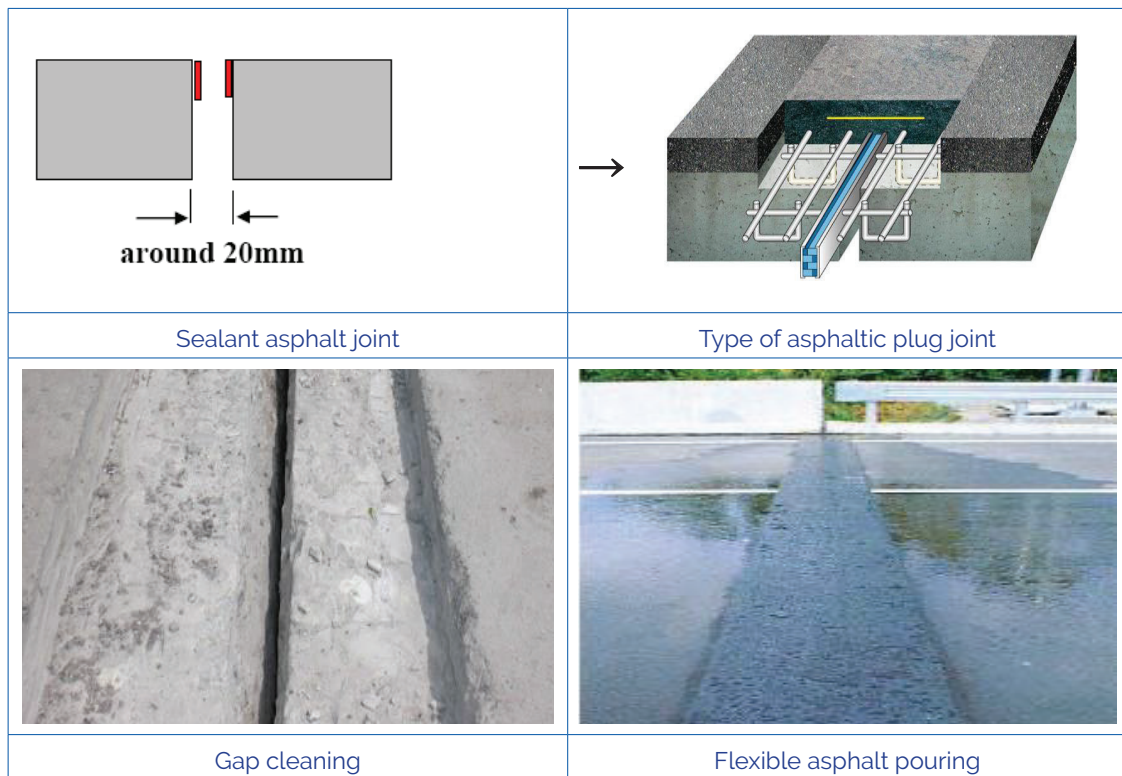


Figure 3.66 Asphaltic plug joint

Scope of Works

The scope of repair works on expansion joints covers both concrete and steel girder bridges on fixed bearings. This repair method shall be implemented if the following conditions are rated as "Bad" as per suggested condition rating criteria:

- Water leakage: Detected area >50%,
- Abnormal space/noise: detected,
- Difference in elevation: >30mm at expansion gap,
- Deteriorated sealant: Pourable joint sealant almost completely lost.

Required Materials and Tools/Equipment & Personnel

i. Required materials

- Steel frame (welded with anchor rebar)
- Concrete anchor with steel bar
- Expansion sheet
- Foam
- Flexible asphalt or asphalt-rubber chip

ii. Required tools/equipment

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

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- Provision of PPE's for the staff or labourers,
- Implementation of safety regulations as per the traffic management plans,
- Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.34 Asphaltic joint repair

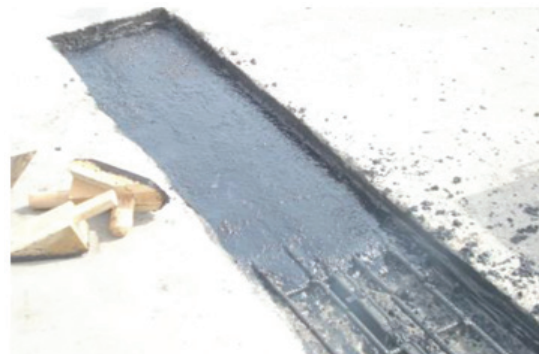
i. Dismantle existing damaged asphalt joint sealant The damaged joint sealant shall be dismantled and removed for appropriate disposal.	
ii. Chipping surface concrete The surface of concrete at the location of the existing damaged joint shall be chipped off for purposes of installing new steel frame and to insert the foam to narrow gap (proper gap for seamless joint is less than 25mm).	
iii. Install steel frame and foam Steel frame shall be fabricated in a box frame and rebar. This frame shall be fixed by welding between concrete anchor and rebar as specified and approved by the Engineer.	

iv. Rebar anchor

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

v. Pouring flexible asphalt 1st layer

Flexible asphalt shall be poured to the chipped off edges and compacted. The height of pouring is half of total thickness to be installed.



vi. Installation of expansion sheet

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

vii. Pouring flexible asphalt 2nd layer

Flexible asphalt (asphalt-rubber chips) shall be poured as second layer.

The surface of flexible asphalt shall not be trafficked until the temperature falls to room temperature.



viii. All works to be done to specifications as approved by the Engineer.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual inspection, watertightness test, space test and alignment test as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payment

Measurement shall be in linear meters (m).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for the repair of asphaltic plug joint as detailed in plans and specifications.

3.3.5.2 Replacement of Expansion Joint

Definition

This refers to the removal of the defective joint in parts or full, and reinstatement.

This can be either;

- Partial replacement of expansion joint,
- Full replacement of expansion joint with a similar type,
- Full replacement of expansion joint with a different type.

The behaviour of the bridges and their durability depends on the quality and maintenance of the expansion joints. 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. The expansion joint shall be replaced if it deteriorates beyond a certain level.



Figure 3.67 Sample of waterproof type expansion joint

Scope of Works

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. 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: >30mm at expansion gap,
- Displacement: Pourable joint sealant may be almost completely lost,
- Cracking: Cracking on primary members especially in welded parts.

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

- Water leakage: Detected area >50%,
- Abnormal space/noise: Detected,
- Difference in Elevation: >30mm at expansion gap,
- Rupture: Rubber seal dislodged or peeled-off,
- Abnormal space/noise: Detected,
- Deteriorated sealant: Joint sealant maybe almost completely lost.

Required Materials, Tools/Equipment & Personnel

i. Required materials

- New expansion joint with water proof rubber
- Rebar (16 mm dia.)
- Concrete/grout
- Fuel

ii. Required tools/equipment

- Concrete cutter
- Electric impact hammer/small jackhammer
- Electric concrete vibrator
- Trowel
- Generator

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

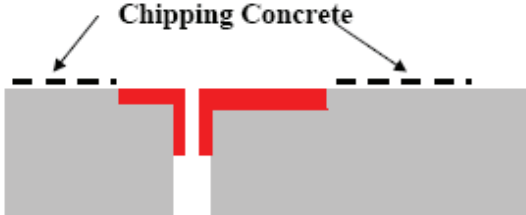
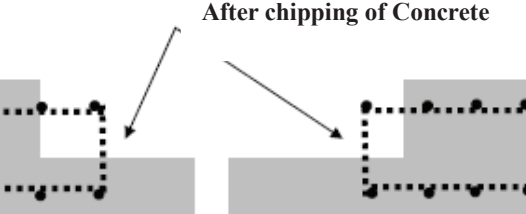
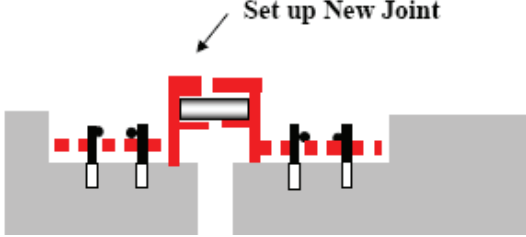
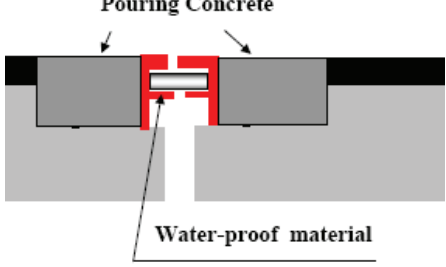
Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

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, levelled, and then cured.

Table 3.35 Replacement of expansion joint

i. Cut concrete surface Using a concrete cutter, concrete surface shall be cut in transverse direction.	 Chipping Concrete
ii. Chipping off concrete/dismantling 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 the concrete.	 After chipping of Concrete
iii. 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.	 Set up New Joint
iv. Pouring concrete After verification measurements, concrete shall be poured, and then cured, to complete the works.	 Pouring Concrete Water-proof material
v. Quality control All works shall be done in accordance with the specifications and as approved by the Engineer.	

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test - Visual inspection, watertightness test, space test and alignment test as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payment

Measurement shall be in linear meters (m).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for replacement of the expansion joint as detailed in plans and specifications.

3.3.6 Major Repair Methods in Bridge Bearings

Major repair methods carried out to bridge bearings are; replacement of bearings, extension of bearing seat, jacking up of girders and repainting of steel bearings.

The defects addressed in this section of the manual are listed in Table 3.36.

Table 3.36 Defects addressed in major repairs to bridge bearings

Classification	Repair/Strengthening Method	Method	Defects Addressed
Major Repairs/ Process	Repair	Replacement of bearings	Cracking Severe bulging Improper anchorage
	Repair	Extension of bearing seat	Spalling Delamination Cracks Breakouts
	Process	Jacking up of girders	Misaligned bearings Replacement of bearings
	Repair	Repainting of steel bearings	Corrosion

3.3.6.1 Jack Up Girder

Definition

This method is applied for replacement of bearings and re-arrangement of existing bearings.

Scope of Works

The computation of jack-up reaction shall be the responsibility of the designated Structural Engineer with an input of the Contractor's structural engineer. Once the required quantity and capacity of hydraulic jacks are determined, this process shall 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 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.



Figure 3.68 Sample of replacement bearing by jacking-up girder

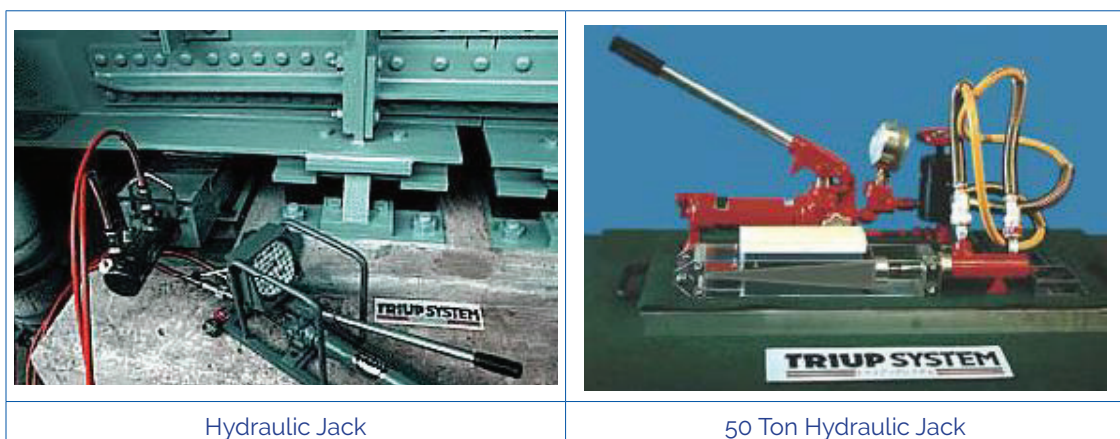


Figure 3.69 Sample hydraulic jacks

Required Materials, Tools/Equipment & Personnel

- i. Required tools/equipment
 - Hydraulic Jacks
- ii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

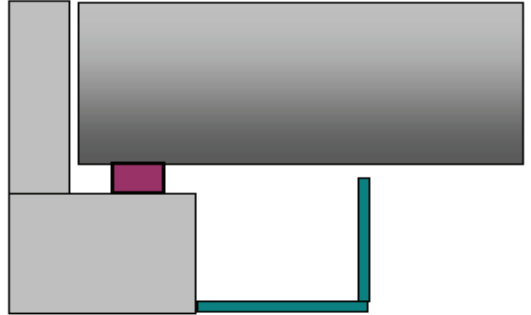
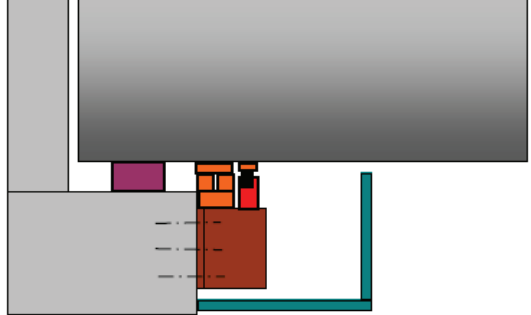
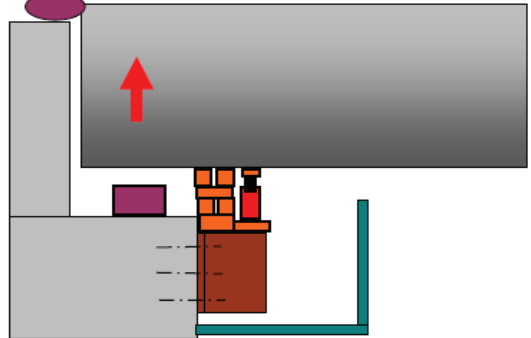
Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

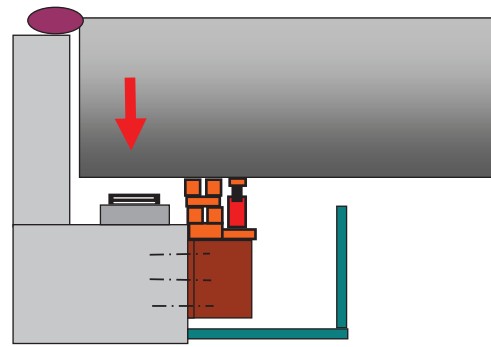
Below is the detailed sequence of carrying out the exercise:

Table 3.37 Jacking up girder

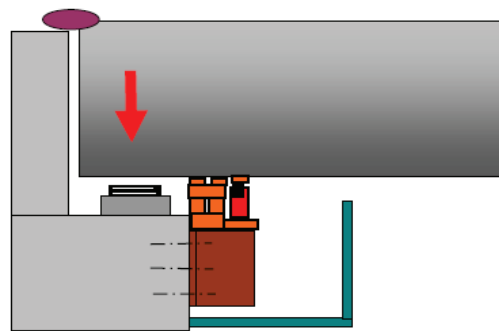
i. Assemble scaffolding The scaffolding is installed to prepare jack-up method to proceed. The jack base bracket shall be fabricated in the factory which is approved by the Engineer.	
ii. Installation of Jack base frame The Jack-base bracket is installed using epoxy anchor through drilled holes for anchor bolts. Hydraulic jack with capacity furnished by designated structural engineer is set up on the jack-base bracket. Temporary supporting members shall also be provided.	
iii. 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.	

iv. Jack down

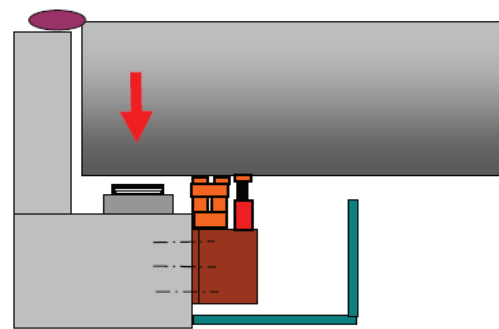
After the main works that required jacking up are done, jack down operations shall commence. It is important to maintain safety during this operation. Jacking down shall be carried out gradually while carefully removing the temporary supporting members.



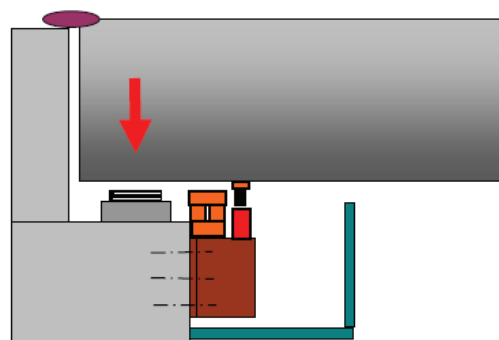
If the temporary support touches the lower surface of the girder during jack down operations, the jack base plate shall be changed with a lesser thickness. Stroke shall be extended to jack down. These steps shall be repeated in cycle. For safety purposes, each stroke should maintain a height of less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



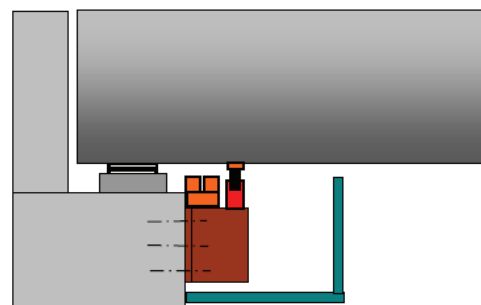
If the temporary support keeps touching the concrete surface, dismantle jack and remove jack base plate gradually.

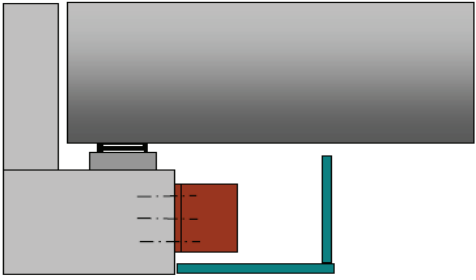
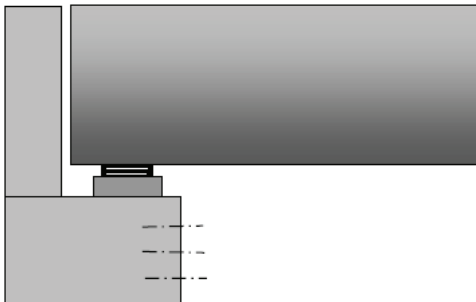


The temporary support shall be taken off from the concrete surface by jacking up slightly. The temporary support shall be dismantled gradually for every 5 mm jack down movement.



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.



v. Dismantle jacks and temporary supports	
Jacks and temporary support materials shall be dismantled.	
vi. Completion	
Clean-up site and ensure the measurements are approved by the Engineer.	

Monitoring and Evaluation

Monitoring of realignment and plumbness after jacking down by the Engineer.

Measurements and Payment

Measurement shall be in number of jacks used.

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for jacking up the girder as detailed in plans and specifications.

3.3.6.2 Replacement of Bearing

Definition

This refers to the removal of the defective bearings in parts or full, and reinstatement.

This can be either;

- Part replacement of bearing,
- Full replacement of bearing with a similar type,
- Full replacement of bearing with a different type.

A bridge bearing is a component of a bridge which typically provides a resting surface between bridge piers and the bridge deck. The purpose of a bearing is to allow controlled movement and thereby reduce the stresses involved.

The possible causes of movement are thermal expansion and contraction, creep, shrinkage, or fatigue due to the properties of the material used for the bearing. 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 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 forms part of the jack-up girder. The capacity of the new bearing should be the same as the old bearing, subject to approval of the Engineer.

Scope of Works

- It involves utilization of jack-up girder technique to allow for replacement of bearings. The respective girder shall be jacked up from 5 mm to 10 mm with one jack stroke.

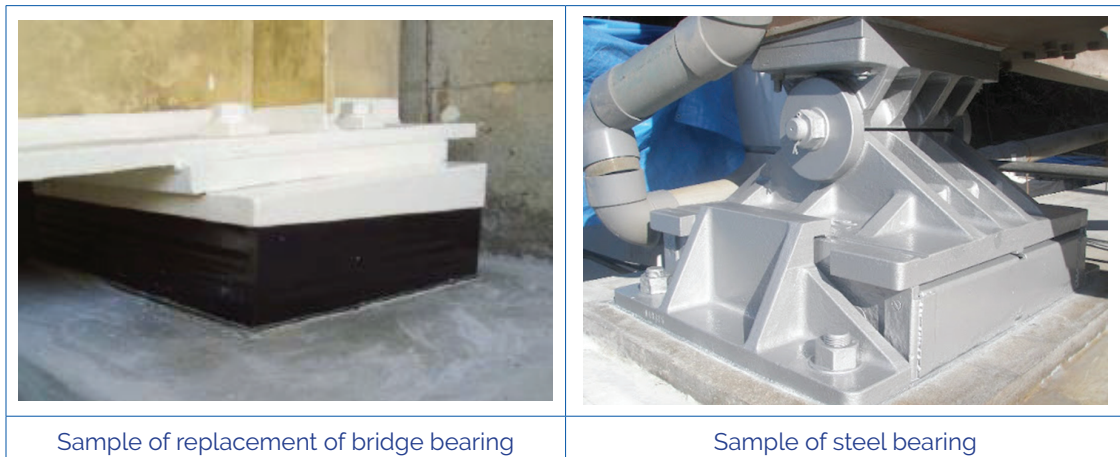


Figure 3.70 Replacement of bridge bearing

Required Materials, Tools/Equipment and Personnel

- i. Required material
 - Elastomeric bearing pads
 - Rebars
 - Mortar/concrete
- ii. Required tools/equipment
 - Hydraulic jack
 - Electrical jackhammer
 - Trowel
- iii. Required personnel

Skilled Personnel trained by KIHBT and Registered/Accredited by NCA.

Preparation for Works

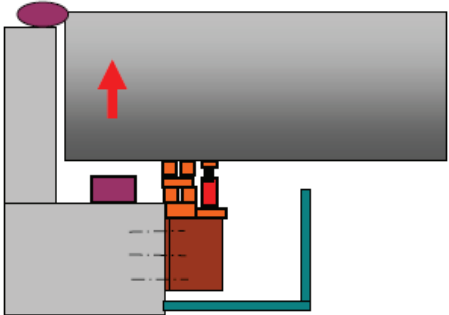
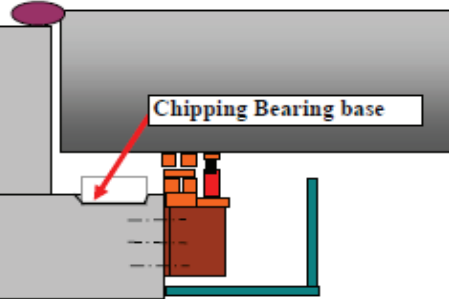
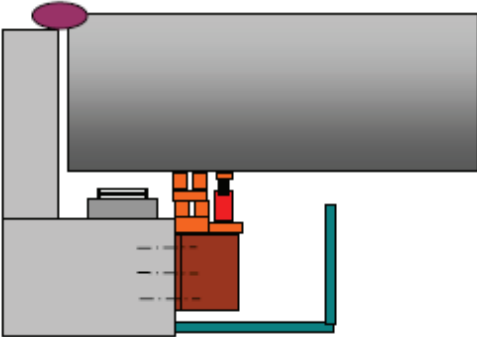
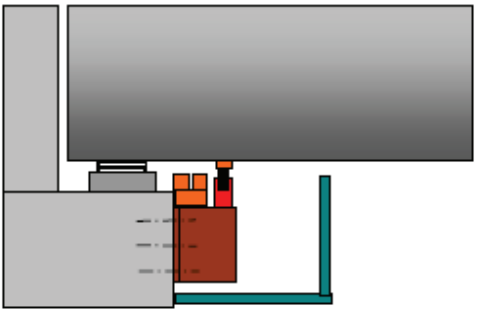
- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

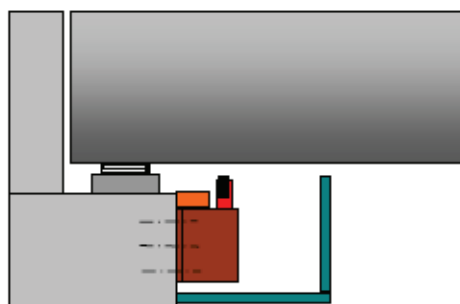
Work Sequence

Table 3.38 Replacement of bearing

i. Jack up girder The surface of expansion joint of the jacked up girder 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.	
ii. Dismantle existing bearing and chipping bearing base After jacking-up process, chip-off concrete bearing base to remove existing bearings.	
iii. 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.	
iv. Jack down girder after curing After curing of bearing bed, 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.	

v. Dismantle jacks and temporary support 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



vi. All work shall be done in accordance with the specifications and as approved by the Engineer.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Visual inspection, anchorage test and alignment test as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payment

Measurement shall be in number of bearings replaced.

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for replacement of the expansion joint as detailed in plans and specifications.

3.3.6.3 Extension of Bearing Seat

Definition

The bearings transmit all the loads (dead load, live load, wind pressure, and others) from the superstructure to the substructure. Consequently, the reaction is concentrated near the bearing seat. This sometimes causes damage to the bearing seat.

Bearings are sometimes installed close to the edge of the concrete coping. There are cases that these coping edges break off due to support reactions from traffic impact loading. This signifies risk of superstructure collapse as the required bearing seat will be reduced. Hence, this repair method is intended to eliminate said risk by extending further the existing bearing seat.

Scope of Works

The repair method involves:

- Complete removal of damaged concrete bearing seat if defects are noted,
- Repair of damaged concrete bearing seat,
- Anchor bars shall be connected to the existing bearing seat to extend the concrete seat width accordingly,
- Concreting the extended bearing seat.

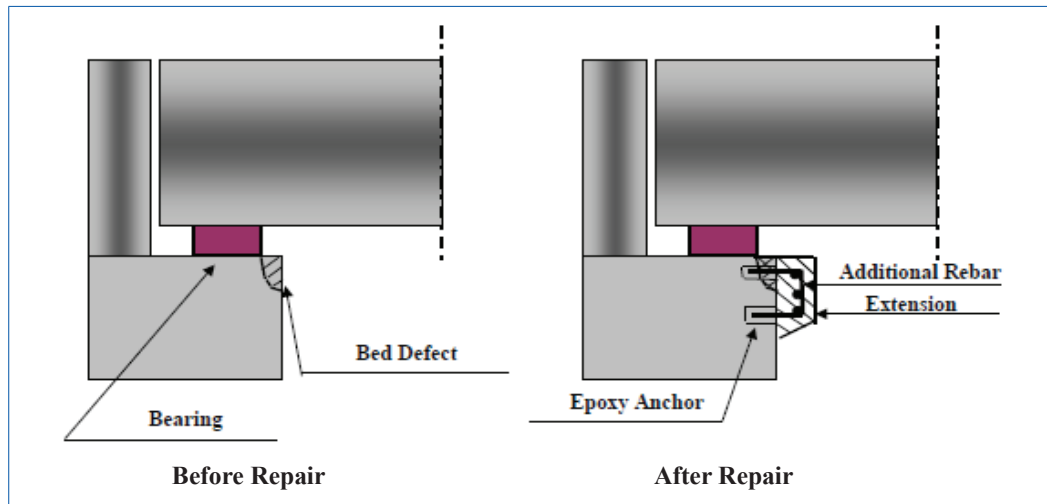


Figure 3.71 Concept of extension of bearing seat

Required Materials, Equipment/Tools and Personnel

i. Required materials

- Primer to concrete surface (epoxy adhesive)
- Epoxy anchor bolts
- Formwork
- High strength concrete and/or grouting mortar
- New reinforcement bars to specifications
- Anchor bars to specifications.

ii. Required tools/equipment

- Electric drill
- Electric concrete vibrator
- Trowel
- Hammer
- Concrete pump
- Water bowser
- Electric jackhammer for chipping

iii. Required personnel

Skilled Personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

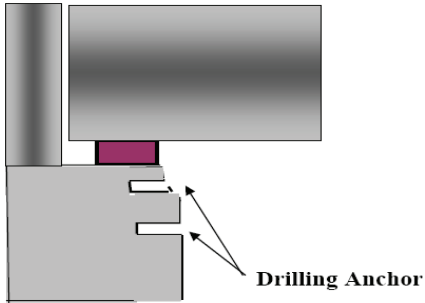
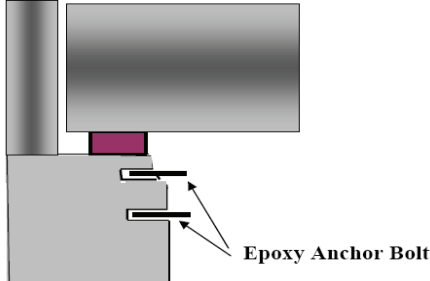
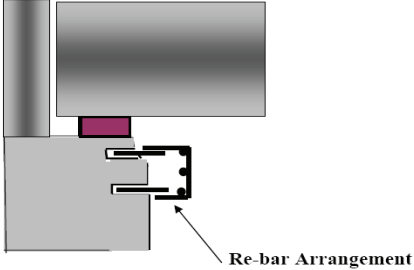
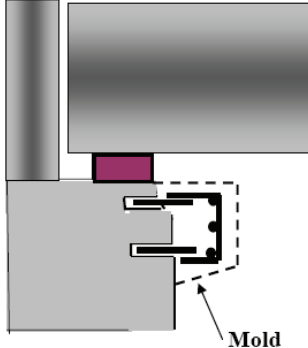
- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

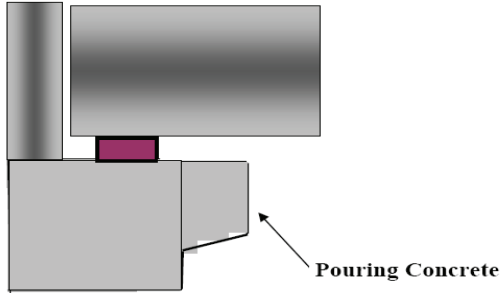
Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.39 Extension of bearing seat

i. Chipping and drilling holes The spalled or delaminated portion shall be removed by hammer chipping or electric drilling. Holes for anchor bar shall be drilled using electric drill device. Drilling of holes shall be performed carefully in order to avoid damaging existing coping reinforcements.	 Drilling Anchor
ii. Anchor bar fitting Drilled hole shall be filled with epoxy adhesive before completely placing required anchor bars.	 Epoxy Anchor Bolt
iii. Arrangement of rebars After anchor bars bond with the drilled holes, new rebars, connected to the anchor bars, are arranged for the proposed extension of bearing seat.	 Re-bar Arrangement
iv. Formwork Formwork and required temporary supports are fixed immediately after application of bonding coats to concrete substrate and reinforcement.	 Mold

v. Pouring concrete Concrete is then poured to the formed section. After concrete is completely in place, finishing and curing is performed. The rendered surface should match that of the existing structure. Formworks shall be finally dismantled.	
vi. Curing The concrete surface shall be cured three times a day for a minimum of 7 days.	
vii. All works shall be done in accordance with the specifications and as approved by the Engineer.	

Monitoring & Evaluation

Monitoring and evaluation of repaired section by the Engineer.

Performance Test - Visual inspection, compressive strength test, bonding test, shrinkage test and alignment test as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payment

Measurement shall be in cubic metres (m³).

Payment shall include full compensation for removal of deteriorated concrete, surface cleaning and preparation, furnishing and placing all materials, labour, equipment and tools as well as construction and removal of formworks and other temporary works necessary to complete this works.

3.3.6.4 Repainting Steel Bearing

Definition

This refers to the application of a new coat of paint to a steel bearing surface that was initially painted.

Typically, due to the deterioration of water proofing at expansion joints over the years, steel bearings underneath the superstructure are subjected to corrosion.

Scope of Works

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%.

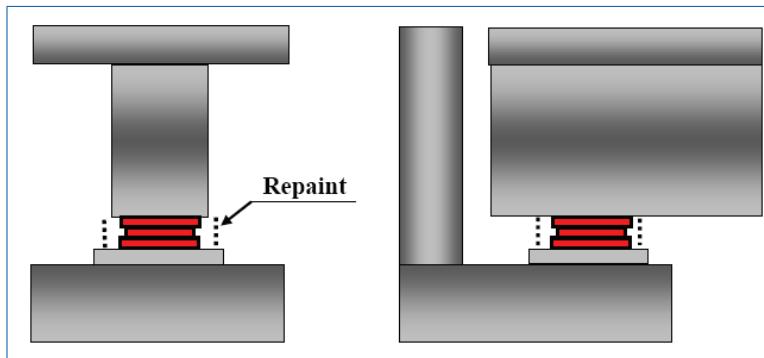


Figure 3.72 Repainting of steel bearing

Required Materials, Equipment/Tools and Personnel

i. Required materials

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

ii. Required tools/equipment

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

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Works Sequence

This repair method is basically similar to requirements in the section of repainting and anti-corrosion paint.

i. Scaffolding

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

ii. Surface preparation for steel bearings

Surface preparation for steel bearings is requisite to repainting required. The surface preparation classification shall be as described in touch up painting.

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.

Monitoring & Evaluation

Monitoring of repainted section by the Engineer.

Performance Test: Pigment or coating depth test, abrasion resistance, adhesion and resistance tests (water, chemical and fire) as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payment

Measurement shall be in square meters (m²).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for repainting steel bearing as detailed in plans and specifications.

3.3.7 Major Repair Methods in Underpinning Foundations

The repair methods carried out during underpinning of foundations are; pit or mass concrete method, pile method, jack pile method, root or angle piling method, pynford stool method and underpinning columns/piers/piles.

Underpinning is a method used to repair and strengthen the foundation of a building or structure. During underpinning, reinforcements are positioned throughout the length or breadth of an already established base. Because of this, its weight is distributed across a larger area and rests on solid earth layers. Micro-piling and jet grouting are common underpinning methods, despite being time-consuming and costly.

The defects addressed in this section of the manual are listed in Table 3.40.

Table 3.40 Defects addressed in underpinning foundations

Classification	Repair/Strengthening Method	Method	Defects Addressed
Major Repairs	Repair	Pit or mass concrete method Pile method Jack pile method Root or angle piling method Pynford stool method Underpinning columns/piers/piles	Settlement Lateral movement Scouring Sapping

3.3.7.1 Pit or Mass Concrete Underpinning

Definition

It involves excavating pits below the existing foundation and pouring mass concrete into the excavated pits to provide additional support and stability hence strengthening and stabilizing the existing structure.

Scope of Work

It involves increasing the size of the present foundation to specifications. Stages or pegs are used to reveal the soil beneath the current foundation. After the desired layers have been reached, the excavation is backfilled with concrete and left to dry before the next removal process can begin.

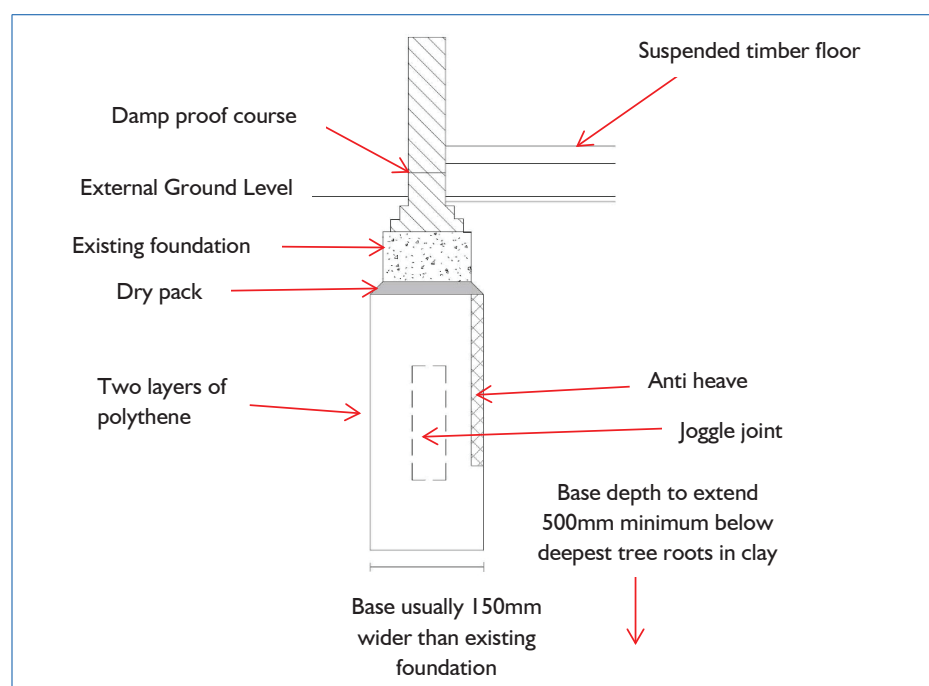


Figure 3.73 Pit or mass concrete underpinning

Required Materials, Equipment/Tools and Personnel

i. Required materials

- Anchors or Tendons
- Formwork
- Cementitious Mortar or Adhesive
- Grout
- Reinforced concrete (Class 25)
- Concrete and steel piles

ii. Required tools/equipment

- Concrete mixers
- Grouting pumps
- Excavators
- Fastener devices
- Laser and spirit levels
- Hydraulic jack and pump
- Grinder
- Generator
- Welding machine
- Hammers
- Wrenches
- Pliers
- Chisels
- Saws

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. Survey and marking

Conduct a detailed survey of the areas to be underpinned and mark the specific locations for excavation. This should be based on engineering calculations and drawings provided.

ii. **Installation of temporary support**

Install temporary support structures (needles or steel beams) to ensure the stability of the existing structure during the excavation process.

iii. **Excavation and cleaning**

Carefully excavate the pits, removing any loose or unstable soil to create a clean surface for pouring the mass concrete. Remove any debris or loose material from the pits to ensure a solid foundation. Compact the resultant surface.

iv. **Preparation for concrete pouring**

Place a layer of blinding concrete (Class 15) or a suitable levelling material at the base of the excavated pits to provide a stable foundation for the mass concrete.

Install reinforcement bars (rebar) if specified in the design to enhance the structural strength of the underpinning.

v. **Concrete mixing and pouring**

Prepare the mass concrete mix of Class 25, pour the mass concrete into the excavated pits, making sure it completely fills the pits and forms a solid foundation. Concrete should be evenly distributed and compacted to eliminate air pockets.

vi. **Curing and setting**

Allow the mass concrete to cure and set according to Engineer's recommendation to achieve the desired strength and stability.

vii. **All works shall be done in accordance with the specifications and approved by the Engineer.**

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test: Compressive strength test, settlement checks and visual inspection as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be made as guided and instructed by the Engineer.

Payment shall be made based on all activities involved during the entire process of underpinning.

3.3.7.2 Pile Underpinning

Definition

The pile method of underpinning is a technique used to strengthen or stabilize the foundation of a structure, typically when the existing foundation is inadequate or unstable.

Scope of Work

This method involves driving or installing piles into the ground beneath the existing foundation to transfer the load of the structure to a more stable and stronger layer of soil or rock.

The borehole is normally supported by piles that have been under-reamed. Steel or concrete “needles” are regularly driven into the wall and connected to the foundation piles. These metal or cement piles serve as a support structure and a pile cap. Water-logged soils, clay, and shaky bearing stratum are ideal conditions for installing underpinning piles.

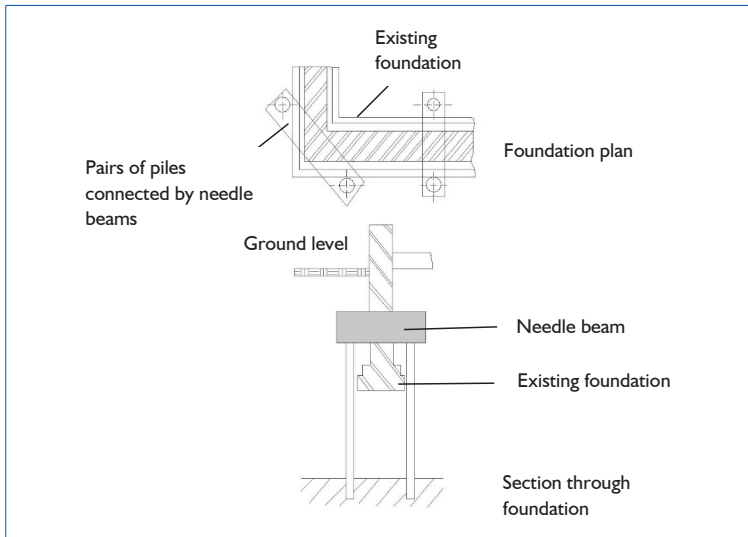


Figure 3.74 Pile method of underpinning

Required Materials, Equipment/Tools and Personnel

i. Required materials

- Anchors or tendons
- Formwork
- Cementitious mortar or adhesive
- Grout
- Reinforced concrete
- Concrete and steel piles

ii. Required Tools/Equipment

- Concrete mixers
- Grouting pumps
- Excavators
- Fastener devices
- Laser and spirit levels
- Grinder
- Generator
- Welding machine
- Hammers
- Wrenches
- Pliers
- Chisels
- Saws

iii. **Required Personnel**

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. **Preparation and excavation**

Clear the area around the foundation and mark the locations where the piles will be installed.

Excavate holes at each marked location to the specified depth where the piles will be inserted.

ii. **Pile installation**

Install the piles using appropriate techniques such as driven piles, drilled piles, or screw piles depending on the design and site conditions.

Drive or drill the piles into the ground to reach the desired depth and ensure they are properly embedded in the stable soil or rock.

iii. **Additional structural support**

Integrate additional structural elements, such as caps, beams, or tie beams, to connect and distribute the load among the piles and provide additional stability.

iv. **All works shall be done in accordance with the specifications and approved by the Engineer.**

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Compressive strength test, settlement checks, plumbness test and visual inspection as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be made as guided and instructed by the Engineer.

Payment shall be made based on all activities involved during the entire process of underpinning.

3.3.7.3 Jack Pile Underpinning

Definition

The jack pile method of underpinning is a technique used in construction and foundation engineering to strengthen or stabilize an existing structure's foundation. This method involves driving steel piles into the ground and using hydraulic jacks to raise and support the foundation. It's designed to provide additional support and stability to an existing foundation that may have settled, weakened, or requires reinforcement.

Scope of Works

The jack pile is driven in to the foundation. The pile depth may be adjusted to suit the underlying soil, jack pile underpinning is silent, vibration-free, and adaptable. Since the pile caps are cast directly onto the jack pile heads once the hydraulic jacks have been removed, the condition of the existing foundations is critical.

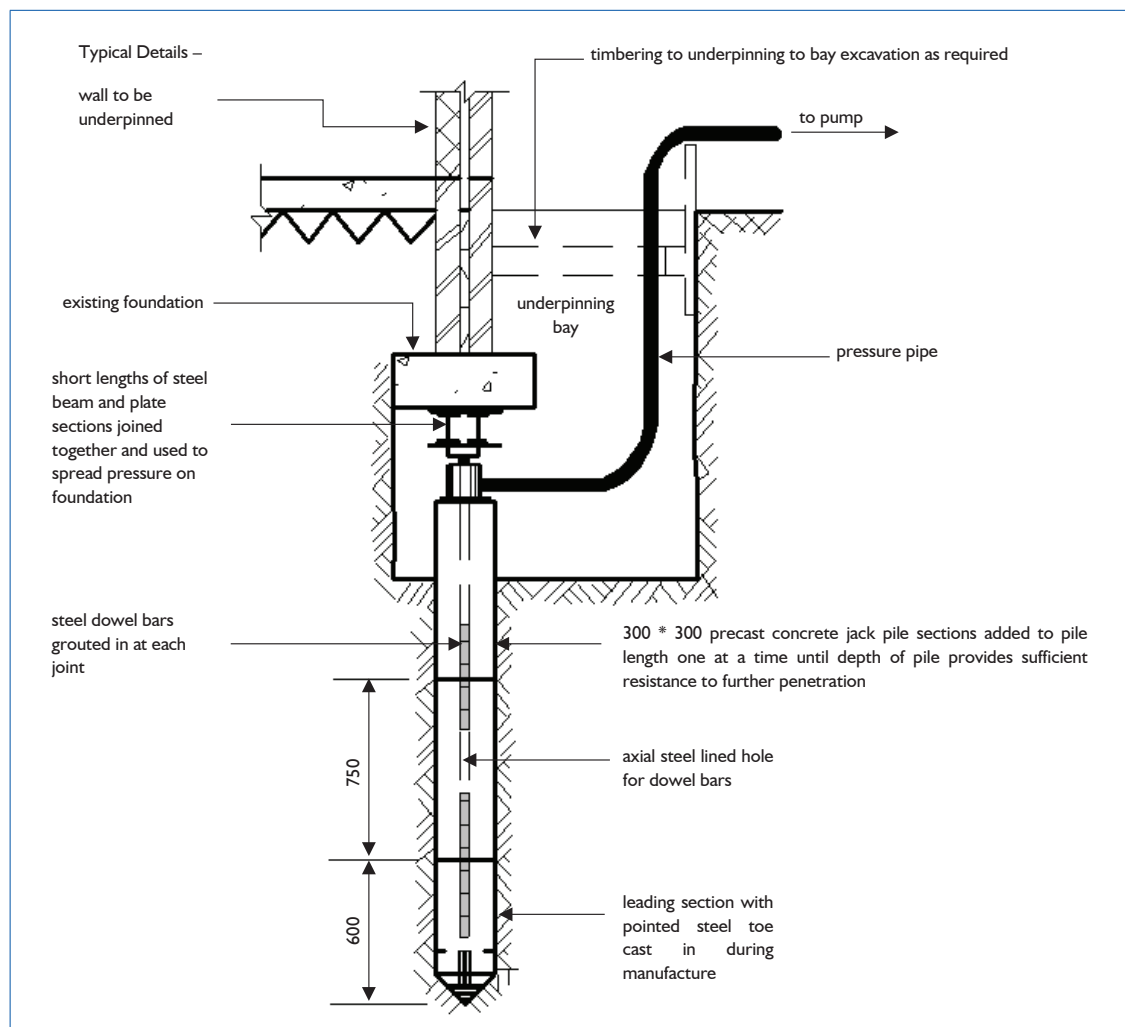


Figure 3.75 Jack pile method of underpinning

Required Materials, Equipment/Tools and Personnel

i. Required materials

- Anchors or tendons
- Formwork
- Cementitious mortar or adhesive
- Grout
- Reinforced concrete
- Concrete and steel piles

ii. Required tools/equipment

- Concrete mixers
- Grouting pumps
- Excavators
- Fastener devices
- Laser and spirit levels
- Hydraulic jack and pump
- Grinder
- Generator
- Welding machine
- Hammers
- Wrenches
- Pliers
- Chisels
- Saws

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. Site preparation

Develop a detailed plan, considering soil conditions, structural load, foundation type, and the number and location of piles required.

Mark the predetermined locations for pile installation around the perimeter of the existing foundation based on the project plan.

ii. **Pile installation**

Use specialized equipment to drive steel piles into the ground at these marked locations until they reach stable soil or rock.

iii. **Hydraulic jacking**

Place hydraulic jacks on top of the driven piles to support the existing foundation and prepare for the lifting process.

Apply hydraulic pressure to the jacks to gradually raise the foundation and transfer the load from the original foundation to the newly installed piles.

iv. **Gradual lifting and load transfer**

Incrementally lift the structure using the hydraulic jacks, monitoring the process to ensure even and controlled lifting.

As the structure is lifted, observe the transfer of the load from the weakened foundation to the new piles beneath, providing support and stability.

v. **Levelling and alignment**

Adjust the lifting process to achieve the desired elevation and alignment of the foundation.

Ensure the structure is levelled evenly, correcting any settlement issues or irregularities in the original foundation.

vi. **Additional structural support**

Depending on project requirements, add additional structural components such as caps, beams, or tie beams to enhance the support and connectivity between the piles and the structure.

vii. **All works shall be done in accordance with the specifications and approved by the Engineer.**

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test: Compressive strength test, settlement checks and visual inspection as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be made as guided and instructed by the Engineer.

Payment shall be made based on all activities involved during the entire process of underpinning.

3.3.7.4 Root or Angle Piling Underpinning

Definition

Root or Angle Piling is a technique used in foundation engineering to stabilize or strengthen the foundation of a structure, especially when dealing with challenging soil conditions or where deep foundation support is required. This method involves installing piles at an angle to provide additional lateral stability and load-bearing capacity to the structure.

Scope of Works

Line pairs of reinforced concrete piles are often installed or driven at right angles to one another. Predrilling using an air-flushed percussion drill reinforces the brick wall without disturbing the subfloor. It might be challenging to install angle piling inside a wall. As a result, they are stacked closely together to ensure their stability.

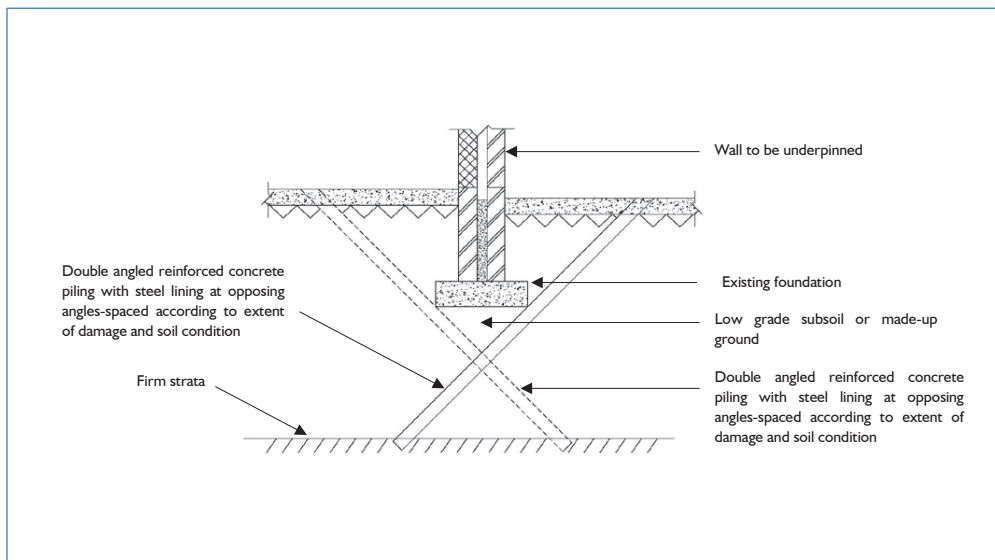


Figure 3.76 Root/angle piling method

Required Materials, Equipment/Tools and Personnel

i. Required Materials

- Anchors or tendons
- Formwork
- Cementitious mortar or adhesive
- Grout
- Reinforced concrete
- Concrete and steel piles

ii. Required tools/equipment

- Concrete mixers
- Grouting pumps
- Excavators
- Fastener devices

- Laser and spirit levels
- Grinder
- Generator
- Welding machine
- Hammers
- Wrenches
- Pliers
- Chisels
- Saws

iii. **Required Personnel**

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. **Site preparation**

Analyze the structural load requirements and determine the appropriate inclination angles for the piles based on the site conditions and engineering calculations.

ii. **Pile installation setup**

Set up the necessary equipment and machinery for pile installation, ensuring they are in proper working condition and comply with safety standards.

iii. **Excavation and drilling**

Excavate or drill holes at the predetermined locations and angles based on the design specifications for the inclined piles. The holes should be inclined relative to the vertical axis.

Ensure the holes are clean, free of debris, and penetrate to the stable stratum.

iv. **Pile installation at an inclined angle**

Install the piles into the inclined holes, following the specified angle determined during the design phase.

Drive or install the piles to the designed depth, ensuring they reach a stable soil or rock layer.

v. **Grouting or filling**

Fill the drilled holes with grout or concrete to secure and reinforce the inclined

piles, providing additional stability and strength.

vi. **Load testing and verification**

Conduct load tests on the installed inclined piles to verify their load-bearing capacity and performance.

Adjust the installation or reinforcement if needed based on the test results to meet the required standards.

vii. **Quality control**

All works shall be done in accordance with the specifications and approved by the Engineer.

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test: Compressive strength test, settlement checks and visual inspection as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be made as guided and instructed by the Engineer.

Payment shall be made based on all activities involved during the entire process of underpinning.

3.3.7.5 Pynford Stool Underpinning

Definition

The pynford stool method is a type of underpinning technique used to support and stabilize existing structures that have experienced subsidence or require additional foundation support.

This method is primarily used to stabilize and strengthen foundations of existing structures, particularly in situations where conventional underpinning methods are not suitable or practical.

Scope of Works

When the current foundations are in poor form, this method can be employed to underpin the wall in one continuous run without using needles or shoring. The resulting reinforced concrete beam could be sufficient to distribute the weight of the existing wall, or it could be used in conjunction with other underpinning techniques, such as regular piles or jack piles.

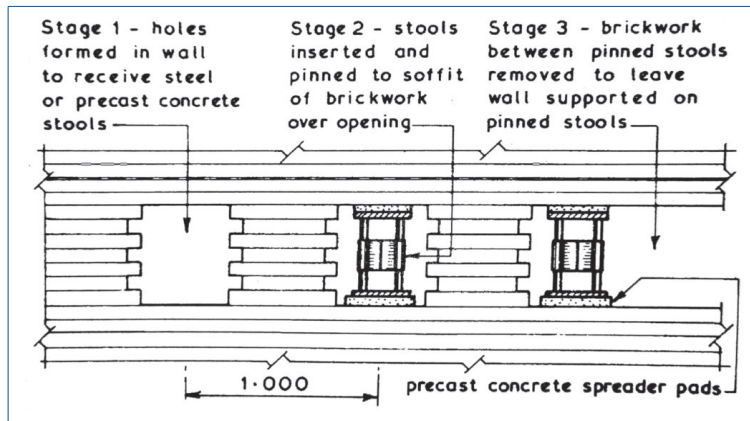


Figure 3.77 Process of Pynford stool underpinning (1/2)

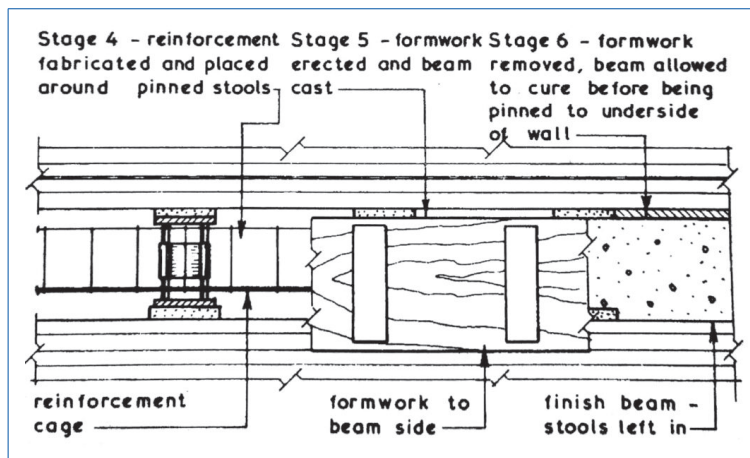


Figure 3.78 Process of Pynford stool underpinning (2/2)

Required Materials, Equipment/Tools and Personnel

i. Required materials

- Anchors or tendons
- Formwork
- Cementitious mortar or adhesive
- Grout
- Reinforced concrete

ii. Required tools/equipment

- Concrete mixers
- Grouting pumps
- Excavators
- Laser and spirit levels
- Hydraulic jack and pump
- Grinder
- Fastener devices
- Generator
- Welding machine

- Hammers
 - Wrenches
 - Pliers
 - Chisels
 - Saws
- iii. **Required personnel**
Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. **Preparation of site**
Clear the work area and ensure access for equipment and machinery. This includes removing obstructions and preparing the foundation area for the underpinning process.
- ii. **Excavation**
Excavate around the existing foundation to expose the foundation footings or base, allowing for access to install the Pynford stools.
- iii. **Installation of pynford stools**
Construct the Pynford stools by drilling or driving reinforced concrete piles into the ground at strategic locations and depths based on the engineer's design.
- iv. **Grouting and reinforcement**
Fill the Pynford stools with grout to reinforce and secure them in place. The grout provides stability and helps distribute the load evenly.
- v. **Removal of masonry in between the stools.**
- vi. **Fabrication and installation of reinforcement around and between the stools.**
- vii. **Fixing of form work.**
- viii. **Casting of concrete ground beam.**
- ix. **Removal of the form work.**
- x. **Curing of the concrete works.**
- xi. **Load transfer**
Gradually transfer the load of the existing structure onto the newly installed

Pynford stools. This may involve carefully jacking and supporting the structure while gradually transferring the load.

xii. **Quality control**

All works shall be done in accordance with the specifications and approved by the Engineer.

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test: Compressive strength test, settlement checks and visual inspection as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be made as guided and instructed by the Engineer.

Payment shall be made based on all activities involved during the entire process of underpinning.

3.3.7.6 Underpinning Columns/Piers/Piles

Definition

Underpinning columns, also known as underpinning piers or foundation underpinning, refers to a structural reinforcement technique used to strengthen and stabilize the foundation of an existing building or structure. The procedure for underpinning columns involves reinforcing and stabilizing an existing building or structure foundation by installing additional support columns or piers.

Scope of Works

Once the columns' loads have been removed, they can be supported in the same way as walls are with conventional or jack piles. When dead beaches are used, beam loads are taken off the columns, and the real column weight is transferred by two beams resting on a collar at the base of the column shaft.

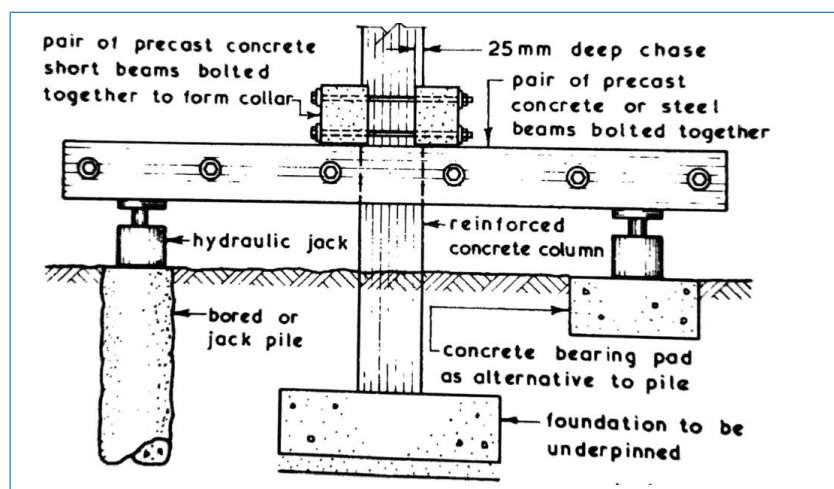


Figure 3.79 Underpinning columns/piles

Required Materials, Equipment/Tools and Personnel

i. Required materials

- Formwork
- Cementitious mortar or adhesive
- Grout
- Reinforced concrete
- Helical piles-screw like steel shafts
- Epoxy resin

ii. Required tools/equipment

- Concrete mixers
- Grouting pumps
- Excavators
- Piling rig
- Rotary drill
- Hydraulic jack and pump
- Laser and spirit levels
- Grinder
- Generator
- Welding machine
- Hammers
- Wrenches
- Pliers
- Chisels
- Saws

iii. Required Personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. Site preparation

Clear the work area around the foundation, ensuring there is adequate space for machinery and equipment. Remove any obstructions and debris from the work area.

ii. **Excavation**

Excavate the area around the existing foundation in a controlled and systematic manner to expose the foundation to the required depth. Excavation is typically done in sections to maintain stability.

iii. **Foundation reinforcement**

Install the additional support columns, piers, or piles to reach a more stable soil layer or rock. The type of columns used may vary based on the engineer's design and the specific soil conditions.

iv. **Column installation**

Install the chosen columns or piers in the excavated holes. Depending on the type, this may involve drilling, driving, or other installation methods. Ensure the columns reach the recommended depth for stability.

v. **Grouting or filling**

Fill the holes around the columns with grout or concrete to provide additional stability and ensure the columns are firmly positioned.

vi. **Load transfer**

Gradually transfer the load of the existing structure onto the newly installed support columns. This is typically done in a controlled and monitored manner to ensure the structure remains stable throughout the process.

vii. **Verification and adjustments**

Verify that the structure is now supported by the newly installed columns and that the load is adequately distributed. Make any necessary adjustments to achieve the desired level of stabilization.

viii. **Backfill and site cleanup**

Backfill the excavated area around the reinforced foundation with suitable materials and compact it properly. Clean up the work area and restore the site to its original condition.

ix. **Quality control**

All works shall be done in accordance with the specifications and approved by the Engineer.

Monitoring & Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Compressive strength test, settlement checks and visual inspection as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurements and Payments

Measurement shall be made as guided and instructed by the Engineer.

Payment shall be made based on all activities involved during the entire process of underpinning.

3.3.8 Major Repair of Bridge Approach Slab Settlement

Definition

The difference in elevation between the approach pavement and the bridge deck results from a complex interaction between the bridge structure, backfill soils and foundation soils; poor drainage is one contributing factor. The settlements can result in unsafe driving conditions, rider discomfort, structural deterioration of bridges and long-term maintenance costs.

Cohesive soils are greater contributors to bridge approach settlement than granular soils because cohesive soils are frost-susceptible, absorb water, settle over time and may become weaker when wet.

The major repair methods carried out for the settlement of the bridge approach slab are; mud jacking/slab jacking and polyurethane concrete raising method.

The defects addressed in this section of the manual are listed in Table 3.41.

Table 3.41 Defects addressed in major repairs to bridge approach slab

Classification	Repair/Strengthening Method	Method	Defects Addressed
Major Repairs	Repair	Mud jacking/slab jacking method. Polyurethane concrete raising method.	Settlement

Scope of Works

Polyurethane concrete raising and mud jacking are two methods used to raise and support sunken or unstable settlement on concrete slabs, by drilling holes and pumping material under the concrete slab.

i. Mud jacking/slab jacking method

Mud jacking – also known as slab jacking or concrete lifting, is a proven, cost-effective method for raising and levelling settled concrete. Tilted sidewalks, uneven patios and cracked driveways are just a few of the problems that can be fixed with this repair method.

ii. Polyurethane concrete raising method

Polyurethane foam method, uses the concrete slab itself as a means of delivering poly foams that raise concrete slab, fill voids, and stabilize soils.

Required Materials, Tools/Equipment & Personnel

i. Required materials

Mud jacking/slab jacking method

- Concrete

Polyurethane concrete raising method

- Polyurethane foam

ii. Required tools/equipment

Mud jacking/slab jacking method

- Concrete drilling machine
- Hydraulic mud jacking pumps
- Mounted paddle grout mixers

Polyurethane concrete raising method

- Concrete drilling machine
- Polyurethane foam injection system with air-purged gun
- Polyurethane concrete raising systems
- Foam slab jacking pumps

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

3.3.8.1 Mud Jacking (Slab Jacking) Repair Method

Mud jacking, also referred to as slab jacking, concrete raising or pressure grouting, is the process of raising concrete slabs by hydraulically pumping a grout mixture, usually sand based material infused with Portland cement, under the slab of concrete.

Work Sequence

The steps for mud jacking/slab jacking process for concrete repair are:

i. Drill mud jacking holes in the concrete slab

To start the mud jacking process, the concrete repair contractor drills several holes in the slab. The holes must be strategically patterned, to effectively raise the slab back to an even position. In most cases, the mud jacking holes will be placed about 600mm to 1200mm apart.

These holes are usually about 50mm in diameter. The number of holes needed for a mud jacking project will vary, depending upon the extent of the concrete damage.

ii. **Pump mud jacking slurry through the holes**

For the next step in mud jacking, Portland cement is combined with water and other materials, such as sand, top soil or limestone aggregate. This mud-like mixture is then hydraulically pumped under the concrete through the drilled holes.

The mud jacking slurry spreads out under the concrete slab as it is pumped, filling empty spaces or voids to stabilize the soil foundation. Once the voids are filled, the cement mixture becomes pressurized, and this is what actually lifts the slab.

Carefully monitor the amount of slurry being pumped into each mud jacking hole, making adjustments as necessary to create an even surface.

iii. **Fill the mud jacking holes and caulk the cracks**

When the slab is level, the mud jacking process is finished. Clean the slurry mixture from the holes and refill them with new concrete.

Most small mud jacking projects take only an hour or two from start to finish. Larger jobs take longer, but are still usually completed within one day. Once the process is finished, the slab is ready for use after waiting for a few hours before putting any significant weight on the concrete.

Following completion of mud jacking, caulking can be done next. Care shall be taken to prevent water ingress. All means should be employed to prevent soil erosion that has the potential to cause slab damage.

iv. **Quality control**

All works shall be done in accordance with the specifications and approved by the Engineer.

3.3.8.2 Polyurethane Concrete Raising Method

Polyurethane foam method, uses the concrete slab itself as a means of delivering poly-foams that raise concrete, fill voids, and stabilize soils.

Raising concrete with polyurethane foam is done with incremental injections. Lifting foam will fully expand within 10-15 seconds allowing one to monitor the raising and preventing over raising the slab.

Using an air-purged gun to deliver foam under the slab. This equipment will keep the injection port open between injections, allowing the foam to fully expand before injecting more foam material.

Work Sequence

- i. Drill 16mm holes through the slab into the pavement.
- ii. Install tapered delivery ports into the drilled holes.
- iii. Connect injection gun to the delivery ports.
- iv. Inject the polyurethane material under the slab through the ports until the approach is attains the required levels.
- v. Seal the holes and clean up the site.
- vi. All works shall be done in accordance with the specifications and approved by the Engineer.

Monitoring and Evaluation

Monitoring and evaluation of the repaired bridge approach slab section by the Engineer.

Performance Test – Settlement checks and visual inspection as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and payments

Measurement shall be in Lump Sum (LS) for the repaired bridge approach slab section.

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for repairing the bridge approach slab as detailed in plans and specifications.

3.4 Replacement of Structure

Definition

Replacement of a structure is the construction of a new structure as a whole, to perform the functions of the old/dilapidated existing structure that can no longer serve its purpose or provide the utility required.

In case where controlled specific demolitions or dismantling are required, it is recommended; a detailed assessment of the whole structure is done, a dismantling design is undertaken, a deconstruction sequence is adopted that meets the complexity that the individual structure requires and all appropriate safety measures are observed.

Scope of Works

The works shall entail replacement of an existing structure with a new one of required load carrying capacity and serviceability. Where the new structure is to be constructed at the location of the existing one, then a temporary passage has to be provided for diversion of traffic to pave way for construction.

Required Materials, Tools/Equipment & Personnel

- i. Required materials
 - Fuel
 - Gravel
 - Steel
 - Concrete
 - Timber
 - PVC
- ii. Required tools/equipment
 - Excavator
 - Roller/vibratory compactor
 - Concrete mixer
 - Poker vibrator

- Air compressor
- Tippers
- Excavators
- Cranes
- Grader
- Wheel loaders
- Hydraulic jack
- Concrete mixer
- Welding machine
- Hammer

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

For the case where the new structure is on a new location;

- i. Removal of existing defective structure observing safety considerations and demolition standards required.
- ii. Clearance of site to remove debris, arisings and the like.
- iii. Construction of the new structure using appropriate construction material and methods as the new structure may require and supervised by the Engineer.
- iv. Installation of the road furniture.
- v. Execution of appropriate protection works as the structure may require.
- vi. Carry out inspection and quality assurance / control as guided by applicable standards and Engineer's instructions.

Monitoring and Evaluation

Monitoring of replaced section by the Engineer.

Measurement and payments

Measurements to be done as per specifications and payments to be made based on interventions undertaken on the structure.

3.5 Emergency Bridge Repair

Definition

It is maintenance required when an asset suffers an unexpected breakdown or change in condition that results in an immediate threat to health and safety. Emergencies always happen without warning, so this type of maintenance cannot be scheduled, but having properly prepared and executed preventive maintenance program will eliminate almost all emergency maintenance, the emergency occurrences that remain can then be handled under this repair.

Scope of Works

Emergency means stressful events that can cause greater damages. Emergency Maintenance (EM) is a type of maintenance intervention that is performed immediately the event occurs. EM is performed to restore the structure back to its normal working condition, it may involve replacement of damaged parts, strengthening or such works aimed at restoring use and ensuring safety.

There can be two types of situations of failures:

- **True emergencies** – These are failures that are very critical and cause greater damage to system. These failures are required to be addressed immediately after failure occurs so that its negative impact can be minimized. These failures are considered true emergencies.
- **Non-emergencies** – These are failures that are not critical and do not cause greater damage to system. These failures do not require to be addressed immediately after failure occurs and can be addressed later whenever possible. These failures are considered non-emergencies.

This emergency repair process outlines repairs to be done under true emergency situations such as:

- Major repair/replacement of slabs,
- Major repair/replacement of railings,
- Major repair/replacement of piers and/or abutments,
- Repair rehabilitation or new construction of check dam when the bridge is at risk from scour,
- Remedial measures as maybe advised by experts after investigations.

Required Materials, Equipment/Tools and Personnel

- i. Required materials
 - Steel members
 - Concrete
 - Hardcore
 - Culverts
 - Gabion boxes
 - Formwork
 - Warning tapes

ii. Required tools/equipment

- Tippers
- Excavators
- Cranes
- Grader
- Wheel loaders
- Hydraulic jack
- Concrete mixer
- Welding machine
- Hammer

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. Reporting and reception of emergency failure information.
- ii. Inventory and condition survey of the existing structure – to conduct an engineering survey of the structure and take immediate steps to shore it up. Roads, entrance and exit ramps and any other adjacent structures that might have been impacted should be inspected and evaluated.
- iii. Design of intended repairs in conformity with existing standards.
- iv. Provide limiting conditions to the structure – as soon as a bridge emergency occurs, inspectors and engineers must work closely with police and local transportation workers to limit access to the damaged bridge by provision of signages and other access limiting systems.
- v. Provision of intermediate access function – In cases where complete blockage has limited the access or reduced access capacity intermediate access provision should be provided so that a level of service of the structure is not affected by the emergency.
- vi. Planning and budgeting of the works – The works budget will be developed and a systematic emergency budget plan held by the road agency to ensure that the emergency is well addressed.

- vii. **Installation of temporary support** – Install temporary structural support, including shoring and bracing, to protect response and recovery workers.
- viii. **Execution of emergency works** – This shall involve undertaking works to meet the emergency needs. These works could involve demolitions, new constructions and the like, to ensure restoration of the structure utility.
- ix. **Quality Assurance** – Provide appropriate supervision for the execution of the emergency works as required.

Monitoring and Evaluation

Monitoring of repaired/replaced section by the Engineer.

Measurements and Payment

Measurements to be done as per specifications and payments to be made based on interventions undertaken on the structure.

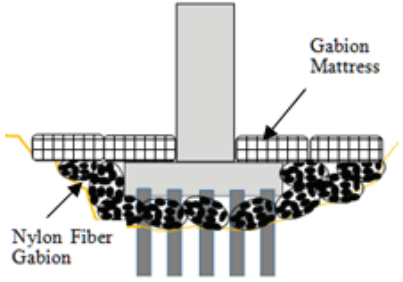
3.6 Repair/Restoration of Protection Works

Definition

Repair to protection works on structures is the use of engineering and non-engineering measures to restore surfaces or installations upstream and downstream for continued protection against excessive wave action, erosion or adverse effects of rapid drawdown. Several defects occur on protection works as shown in Table 3.42.

Table 3.42 Common defects on protection works

Defect	Cause	Mitigation	
Damaged slope protection around the abutment/pier	• Scouring • Rapid river flow • Improper construction-failure to provide foundation for slope protection	• Provision of gabion boxes • Stone pitching • River training • Provision of foundation to the protection work • Vegetation control • Slope patching	
Local scouring around the pier	• Strong stream flow • Weak riverbed materials • Improper foundation.	• Provision of gabion boxes • River training • Proper reinstatement around foundation structures	

Defect	Cause	Mitigation	
Damaged slope protection around the abutments	- Inadequate compaction of slope embankment - Strong stream flow - Insufficient flood drains	Slope patching.	
Local scouring to piles	Strong river flow	- Provision of gabion mattress as a standard repair method - Provision of nylon fibre gabion where the river bed shape is complicated	
Deterioration of columns, piers and piles	- Adverse weather conditions - Lack of proper maintenance	- Jacketing - Reinforced concrete jacketing - Steel jacketing - Fibre reinforced polymer jacketing - Glass fibre reinforced polymer jacketing	
Erosion of slopes/ embankments	- Absence of slope protection - Steep gradient, nature of embankment material	- Stone pitching - Grassing - Provision of gabion boxes - Slope stabilization	
Exposed concrete piles	- River bed degradation - Scouring - Lack of protection around piles	- Restoration of river bed level - Provision of gabion boxes - Concreting around the piles	
Slope failure	- Saturation of soils - Steep slope gradient	- Slope stabilization, - Provision of weep holes	

- Concrete with minimum steel reinforcements
 - Filter fabric sheet (under gabion mattress)
- ii. **Required tools/equipment**
- Vibratory compactor
 - Dump truck
 - Wheelbarrows
 - Masonry tools
- iii. **Required personnel**
- Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

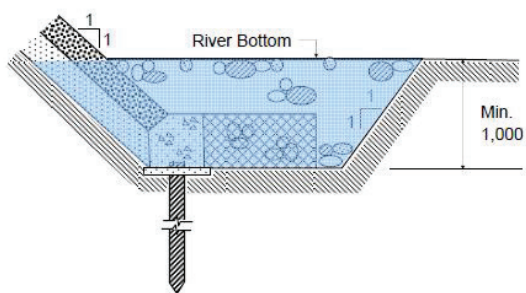
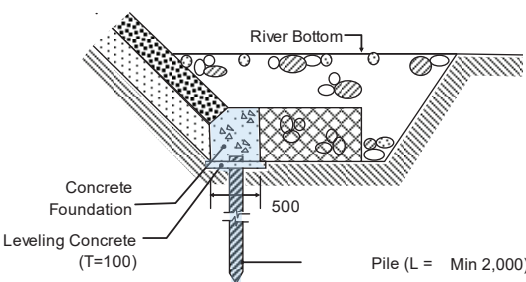
- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

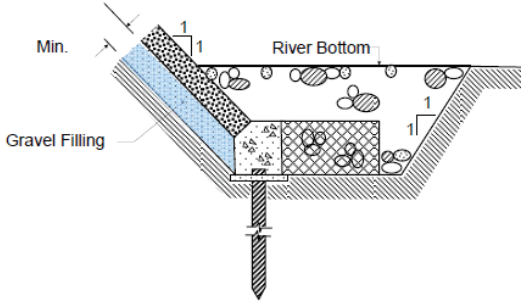
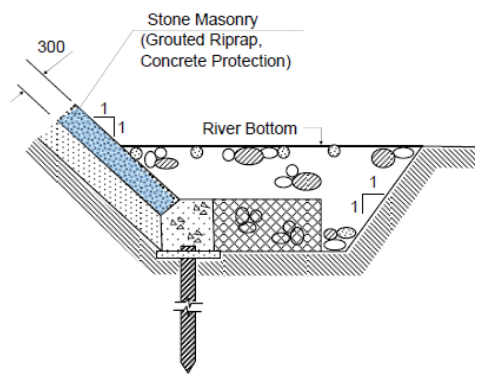
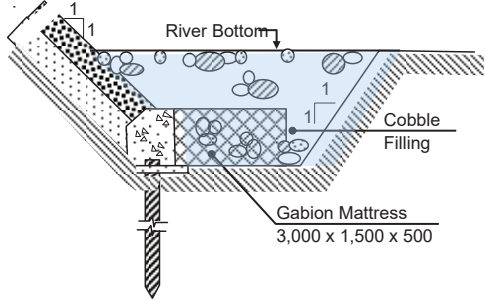
Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.43 Slope protection reinstatement with foundation supported by piles

i. Preparatory works 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.	
ii. Placing concrete foundation 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.	

iii. Quality assurance	
	Supervision by the Engineer to ensure quality assurance and quality control processes are achieved during the works.
iv. Compaction of backfilled gravel	
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.	
v. Placing masonry stones	
Select appropriate masonry stones from the variety of slope protection works such as stone masonry, grouted riprap and concrete masonry.	
vi. Installation of gabion mattress and backfill with rock	
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.	

Monitoring and evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Compressive strength test, settlement checks and visual inspection as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and payment

Measurement shall be based on lumpsum amount.

Payment shall include full compensation for provision of materials, labour, tools equipment and other necessary accessories to complete the works.

3.6.1.2 Gabions

Definition

Gabion units consist of wire gauge filled with specified material used to prevent erosion or retain slope. Each unit is sub divided into compartments normally to give cells 2m x 1m in plan. Local scouring around the pier and abutment footing and high embankments often occurs due to turbulent stream flow, weak riverbed materials and type of foundation. They are also used to prevent erosion and scouring on culvert inlets and outlets. The worst damage that could occur due to scouring is the exposure and weakening of bridge abutment and 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.

Scope of works

Gabion protection is a simple and effective scour protection method for pier and abutment footing, culvert inlet and outlet and slopes of bridge approaches..

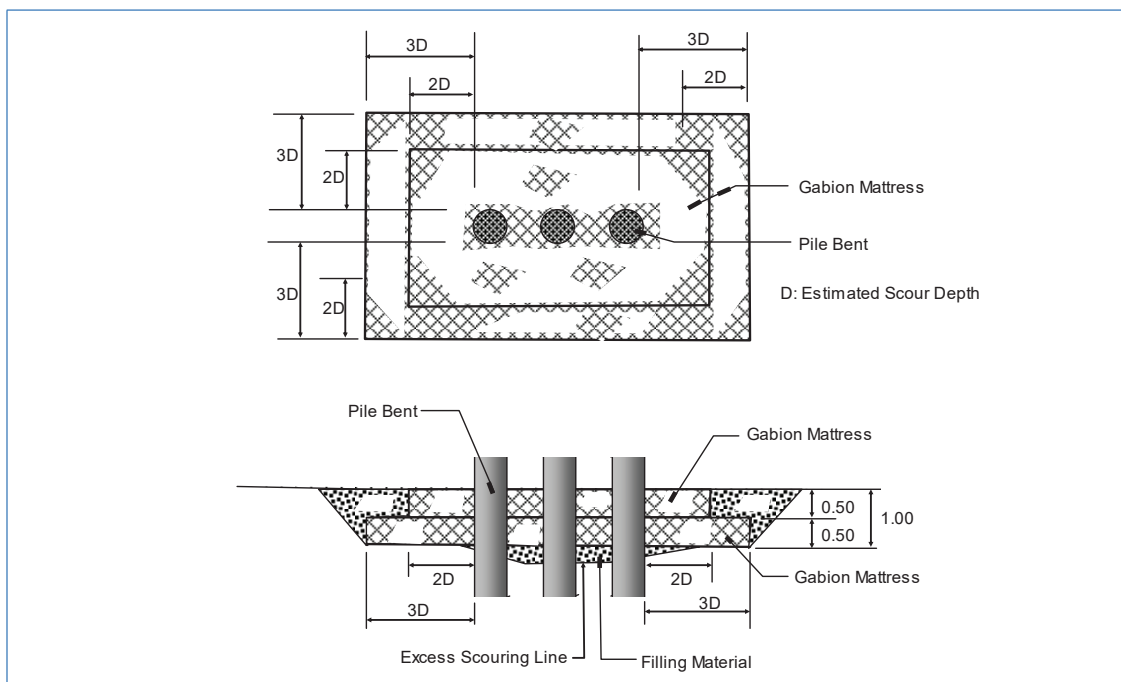


Figure 3.81 Application requirement for standard gabion mattress

Required Materials, Equipment/Tools and Personnel

- i. Required materials
 - Gabion mattress
 - Concrete
 - Rock fill material
 - Filter fabric sheet
 - Backfill materials

ii. Required tools/equipment

- Vibratory compactor
- Dump truck
- Wheelbarrows
- Concrete mixer
- Packer vibrator
- Sledge hammer
- Pick axe

iii. Required personnel

Skilled person trained by KIHBT and registered/accredited by NCA.

Preparation for Works

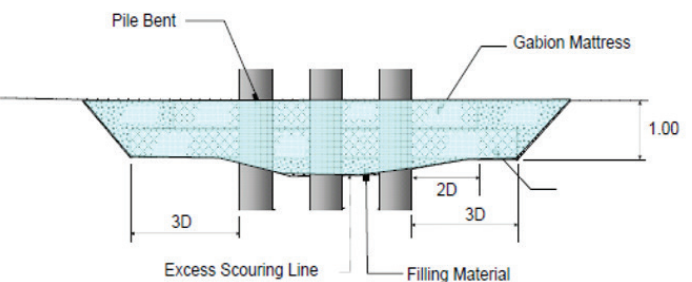
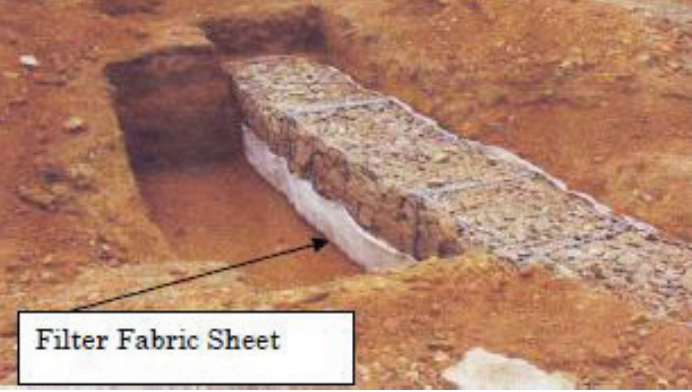
- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- Provision of PPE's for the staff or labourers,
- Implementation of safety regulations as per the traffic management plans,
- Adhere to all environmental, occupational, safety and health regulations.

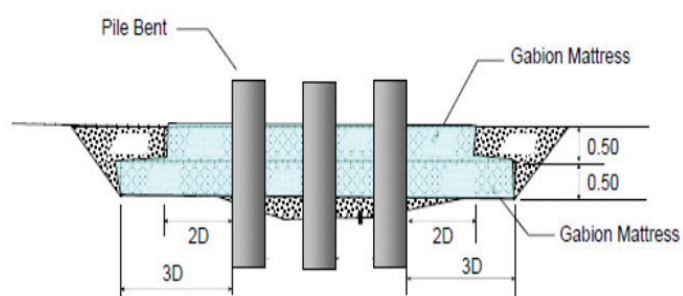
Work Sequence

Table 3.44 Gabion installation

i. Preparation of the bed area for gabion installation Preparation of bed area for gabion installation by such as excavation, backfill and compaction.	
ii. Placing filter fabric sheet A filter fabric sheet shall be spread tightly and pegged with material approved by the engineer. The filter fabric sheet shall be placed with a minimum 30cm overlap.	

iii. Installation of gabions

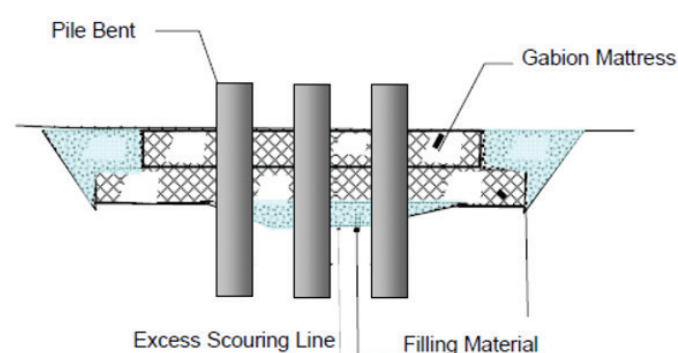
Gabion filling shall be carried out by placing individual stone material into the gabion. When the gabion mattresses are completely filled, the cover panels shall be closed and the edges tied with binding wire as in a typical assembly process. .



The formed mattress shall be completely tight and square ensuring that quality assurance and quality control of the materials used and workmanship is implemented as required by the standards and directed by the Engineer

iv. 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. Backfilling should be in layers as directed by the Engineer.



Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test: Settlement checks and visual inspection as per the Standard Specification for Bridge Repair in Kenya or any other applicable standard.

Measurement and Payment

Measurement shall be based on square meters (m^2) for the gabion mesh and cubic metres (m^3) for the stones.

Payment shall include full compensation for provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.6.1.3 Slope Patching

Definition

Slope protection around the abutment is a restorative measure for a damaged slope due to inadequate compaction, stream flows or insufficient flood drains or accidents.

Scope of Works

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 3.82. New masonry patched into the excavated portion shall consist of 300 mm gravel filling and 300 mm masonry material.

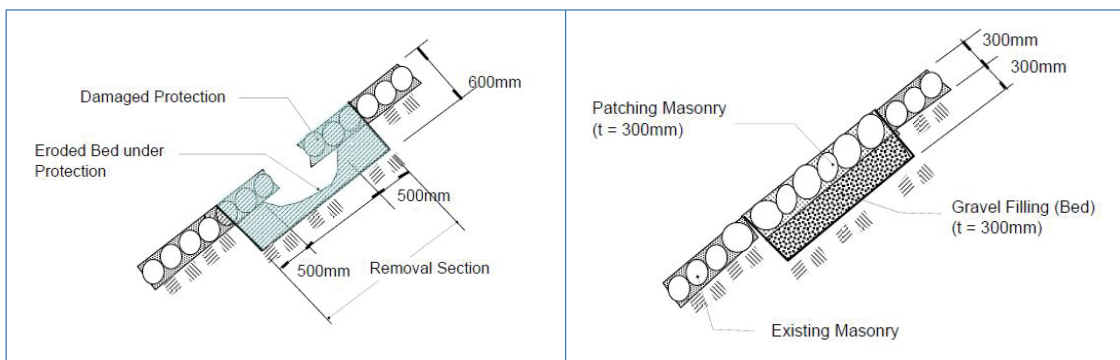


Figure 3.82 Repair requirements to damaged masonry protection

Required Materials, Equipment/Tools & Personnel

i. Required materials

- Masonry materials to specifications
- Crushed stone
- Gravel
- Mortar

ii. Required tools/equipment

- Vibratory compactor
- Dump truck
- Wheelbarrows
- Masonry tools

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

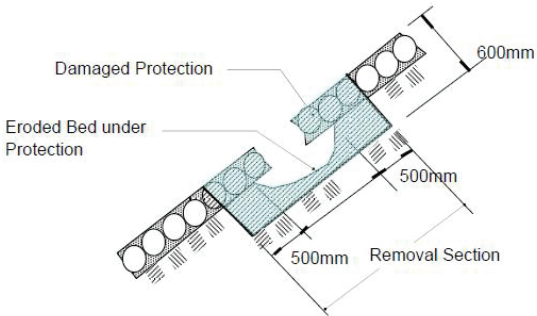
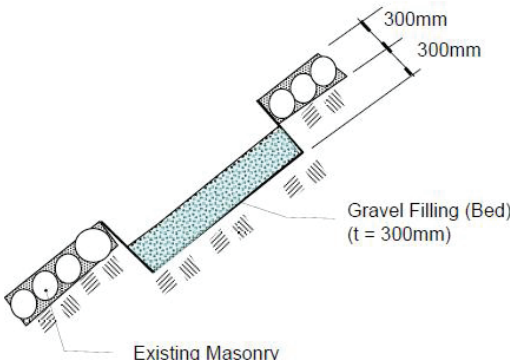
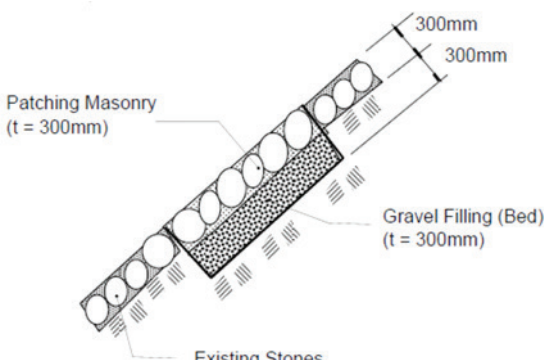
- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.45 Slope patching

i. 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.	
ii. Fill and compact gravel 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 ensuring that each layer is backfilled and compacted as required by the standard and as directed by the Engineer.	
iii. Patching Appropriate masonry material will be selected depending on the type of existing masonry (stone masonry, grouted riprap and concrete masonry).	

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Settlement checks and visual inspection.

Measurement and Payment

Measurement shall be in square meters (m²).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for slope patching as detailed in plans and specifications.

3.6.1.4 Nylon Fibre Gabion

Definition

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, abutment footing, slope foundation, inlet and outlet of culverts, eventually leading to undermining of the base and failure of the bridge. Gabion mattress shall be applied for this defect as standard repair method. Nylon fibre gabion is used for prevention of scour on pier foundation and other underwater structures particularly if the river bed shape is complicated. Thus, protection against local scouring is intended to eliminate or minimize future damage to the bridge substructure.

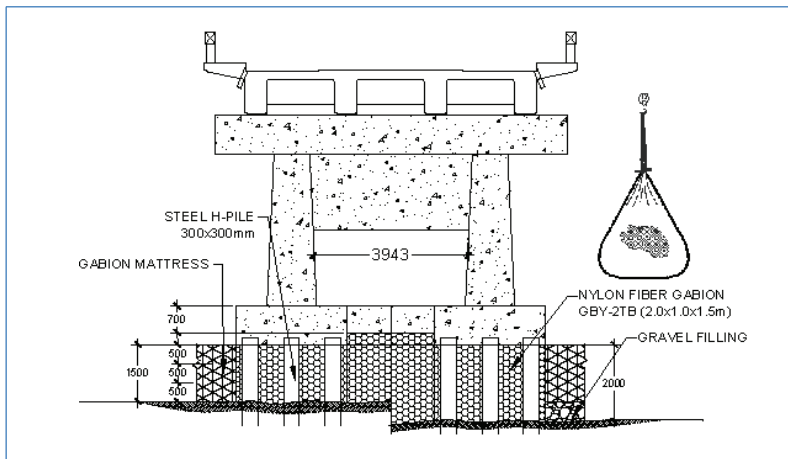


Figure 3.83 Illustration on use of nylon fibre gabion

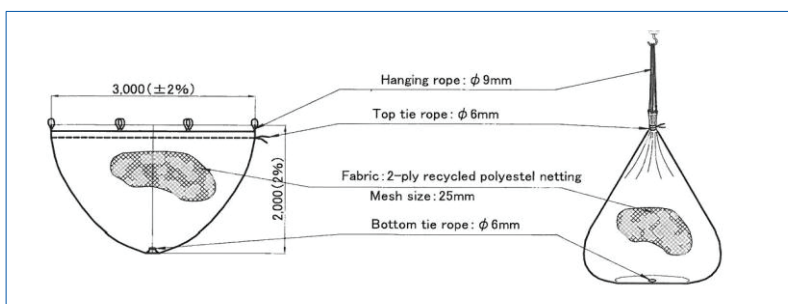


Figure 3.84 Filling of nylon fibre bag

Scope of Works

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 fibre 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.

Required Materials, Equipment/Tools and Personnel

i. Required material

- Nylon fibre gabion
- Knitted fabric material
- Rock fill (boulders)
- Backfill materials

ii. Required tools/equipment

- Backhoe or crane
- Vibratory compactor
- Dump truck
- Wheelbarrows
- Concrete mixer
- Pocker vibrator
- Sledge hammer
- Pick axe

iii. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

Table 3.46 Nylon fibre gabion

i. Place boulders into nylon fibre gabion bag Boulders to be used shall conform to broken rock size requirements gabions in Standard Specifications for Road and Bridge Construction. When filled, nylon fibre gabion weighs 2 tons with equivalent size of 3m x 2m and volume of about 1.24 m³.	
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ii. Transport to scoured area	
After filling with boulders, the nylon fibre gabion shall be transported to scoured area by mechanical means. (back hoe and crane).	
iii. Place nylon fibre gabion using backhoe	
Using backhoe lay gabions in scoured portion.	
iv. Level checks as directed by the Engineer	
Level checks to be done for confirmation of the designed elevations as per design.	

NB: After installation of nylon fibre gabion, gabion mattress shall be placed as surface layer. Requirement of installation is the same as that of gabion mattress as in Section 3.6.1.2.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test – Visual inspection for conformity to the shape where it is placed and passage of water through the bag.

Measurement and Payment

Measurement shall be in cubic meters (m³).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for nylon fibre gabion as detailed in plans and specifications. Any other items of work not covered in this shall be determined by the Engineer.

3.6.1.5 Jacketing

Definition

Jacketing is a method of structural retrofitting and strengthening that is used to increase the bearing capacity following a modification of the structural design or to restore structural design integrity due to a failure in the structural member.



Figure 3.85 Welding of reinforcement bars

Types of Jacketing

A. *Reinforced Concrete Jacketing*

In reinforced concrete jacking, an additional cage of longitudinal and lateral tie reinforcement is provided around the pier. A concrete ring is then cast around the pier. Jacketing a reinforced concrete beam can also be done in the above manner. The stirrup in this case, is held up by drilling holes through the slab.

The reinforcement and concrete used for jacking should be as specified by the Structural Engineer.



Figure 3.86 Reinforced concrete jacking

B. *Steel jacking*

Steel jacking is an effective method to increase bearing capacity. It provides enough confinement and also prevents deterioration of shell concrete, which is the main reason for bond failure and buckling of longitudinal members of a structure.

The section of the column/pier that is defective is encased with steel plates and the gaps filled with non-shrink grout. The most commonly used strengthening technique is by use of steel strips and angles. The jacketing helps to restore strength, ductility and energy absorption capacity of columns/piers.

Steel jacketing is an effective method to remedy deficiencies such as inadequate shear strength, but it may be costly and its fire resistance has to be addressed.



Figure 3.87 Steel jacketing

C. *Fibre Reinforced Polymer (FRP) jacketing*

Fibre Reinforced Polymer (FRP) is a commonly used for retrofitting. FRP is widely used for its properties such as high strength to weight ratio, stiffness, good impact properties, high resistance to corrosion in harsh environmental and chemical condition (making it most useful in sea structure). Use of FRP causes only a minimum alteration to the geometry of the structure compared to other methods of jacketing.



Figure 3.88 Fibre reinforced polymer jacketing

D. Glass Fibre Reinforced Polymer Jacketing

This is the application of composite materials for jacketing developed in strengthening and retrofitting of concrete structures. The design of glass-fibre-reinforced contains basic properties under tensile, compressive, bending and shear forces, coupled with estimates of behavior under secondary loading effects such as creep, thermal response and moisture movement.



Figure 3.89 Glass fibre reinforced polymer jacketing

Scope of Works

Jacketing is used in the repair and strengthening of deteriorated columns, piers, and piles and may easily be employed in underwater applications. The method is applicable for protecting concrete, steel, and timber sections against further deterioration and for strengthening. Jacketing improves axial and shear strength of columns and a major strengthening of the foundation may be avoided.

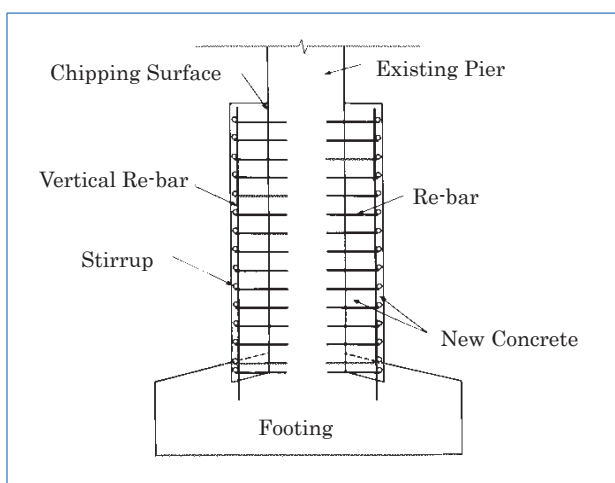


Figure 3.90 Concrete jacketing

Required Materials, Tools/Equipment and Personnel

i. Required materials for concrete jacketing

- Concrete with fine aggregate; A suggested mix design for small scale repairs is given below as reference. These quantities will make about 0.03 m³ of concrete and could be fully accommodated in a small mixer
- Cement
- Portland cement 13.0 kg
- Admixture 0.5 kg (Silica fume)
- 10 mm crushed aggregate 36.0 kg
- Sand (assumed with 2% water content) 18.5 kg
- Water (maximum) 5.4 liters
- Super plasticizer (nominal) 25 ml
- Formwork
 - Steel formwork (Circular)
 - Plywood formwork

ii. Required tools/equipment for concrete jacketing

- Drilling machine to concrete
- Concrete vibrator

iii. Required materials for steel jacketing

- Grout
- Steel plates

iv. Required tools/equipment for steel jacketing

- Drilling machine to concrete
- Welding machine

v. Required materials for Fibre Reinforced Polymer (FRP) jacketing

- FRP
- Epoxy resin

vi. Required tools/equipment for Fibre Reinforced Polymer (FRP) jacketing

- Wire brush
- Epoxy spreader

iv. Required Materials for Glass Fibre Reinforced Polymer (GFRP) jacketing

- Glass FRP
- Epoxy resin

viii. Required tools/equipment for Glass Fibre Reinforced Polymer (GFRP) jacketing

- Wire brush
- Epoxy spreader

ix. Required personnel

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

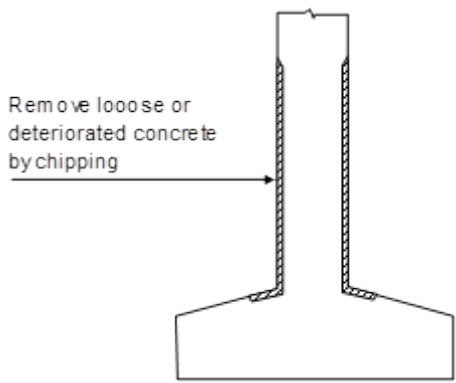
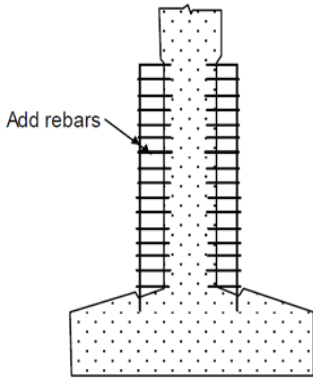
- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

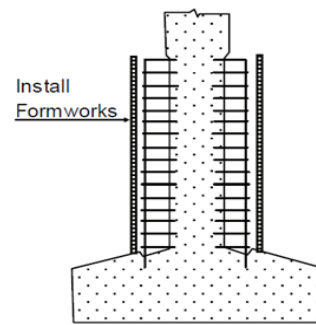
Work Sequence for Concrete Jacketing

Table 3.47 Concrete jacketing

i. Removal of deteriorated existing surface material All loose or deteriorated existing surface material shall be removed to enhance bonding.	 Remove loose or deteriorated concrete by chipping
ii. Addition of rebar, steel plate, fibre reinforced polymer, glass fibre reinforced polymer Appropriate reinforcing materials should be fixed as required.	 Add rebar

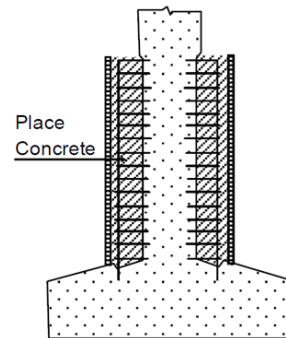
iii. Setting-up formworks as applicable

Formwork for concrete jacket is commonly circular or rectangular in shape. This formwork must be very rigid and well-supported to maintain the shape and the required covering of the new concrete. It should also be able to withstand pumping forces if concrete is to be pumped and vibrated.



iv. Placing of concrete for concrete jacketing

Concrete with an approved mix design is placed in the formworks through a suitable method and compacted well using internal or external vibrators. Surfaces shall be finished using broom, wood floating, and steel trowelling to match the adjacent existing concrete ensuring that rebars, steel plate, fibres and any other reinforcing material used are in conformity to specifications standards and as directed by the Engineer.



v. Curing of concrete

Continuous water curing using wetted cotton mat is preferable to help slow down drying. Formworks for load bearing structural members shall remain in position for a minimum of 21 days.

Work sequence for the other types of jacketing shall be directed by the specifications and approved by the Engineer.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test: Visual inspection, consistency test and bond strength test.

Measurements and Payment

Measurements shall be in tonnes of rebars & steel plate, cubic meters (m^3) of concrete, and square metres (m^2) for Fibre Reinforced Polymer, Glass Fibre Reinforced Polymer and formwork used.

Payment shall include full compensation for provision of materials, labour, tools, equipment and other necessary accessories to complete the works.

3.6.1.6 Grassing

Definition

It is the provision of vegetation cover to minimize flow of surface run off on embankments.

Scope of Works

Plant and maintain grass cover for control of erosion on embankment slopes.

Required Materials, Equipment/Tools and Personnel

- i. Required materials
 - Manure
 - Suitable soil
 - Grass seeds
 - Water
- ii. Required tools/equipment
 - Hand caster
 - Wheeled spreader
 - Landscape rake
 - Lawn mower
 - Garden hose with nozzle
 - Water tanker
- iii. Required personnel

Skilled and unskilled construction workers

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Works Sequence

- i. Prepare area for grassing.
- ii. Establish appropriate grass type for the affected location.
- iii. Plat grass as per the approved method as directed by the Engineer.
- iv. Ensure grass planting and slope quality comply with the stipulated standards.
- v. Water, prune and maintain grass and slopes as required by standards.

Monitoring and Evaluation

Monitoring of grassed section by the Engineer.
Visual inspection of adequacy of grass cover.

Measurements and Payment

Measurement shall be based on square meters (m²).

Payment shall include full compensation for provision of materials, labour, tools, equipment and other necessary accessories to complete the works.



Figure 3.91 Grassing on slope

3.6.1.7 Stone Pitching/Revetment

Definition

Consists of placing medium sized rock set into mortar exposing the stone and is designed to spread and direct the flow of surface run off. Stone pitching is placed on a slope with a gradient of 5% up to 35%.

Scope of Works

This technique is particularly useful on slopes with a heavy seepage problem, in flood-prone areas or where vegetation is difficult to establish, such as in urban areas. It is also useful on gully floors between check dams and for scour protection by rivers.

Required Materials, Equipment/Tools and Personnel

- i. Required materials
 - Masonry stones
 - Cement- sand mortar
 - Suitable fill soil
 - Water
- ii. Required Equipment/Tools
 - Jembe/Hoe
 - Spade

- Trowel
- Mason's hammer
- Slasher
- Panga
- Wheelbarrow
- Lorry
- Water bowser

iii. **Required personnel**

Skilled and unskilled construction workers trained by KIHBT and accredited/registered by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Works Sequence

- i. Prepare a sound slope before constructing the stone pitching; it must be free of loose debris and topsoil, and trimmed to an even surface.
- ii. Bed the stones down well into the slope surface. Excavate as necessary to ensure an even upper surface to the stone pitching.
- iii. Stone pitch with the stones fitted together firmly, and grout as per the methodology approved by the Engineer. Stones should be perpendicular to the slope, with the main point or narrow side down.
- iv. For further strengthening it is best to plant grasses or the hardwood cuttings of shrubs through the stone pitching.
- v. Ensure stones and grout used meet the material and workmanship as required by the Engineer.
- vi. Other options for strengthening are either to use a gabion mattress (0.3 to 0.5 metre thickness) instead of dry-stone pitching; or to use cement mortar (but this can impede drainage).

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance Test: Settlement checks and visual inspection.

Measurements and Payments

Measurement shall be based on square meters (m²).

Payment shall include full compensation for provision of materials, labour, tools, equipment and other necessary accessories to complete the works.



Figure 3.92 Laying of stone pitching

3.6.1.8 Reinstatement of Damaged or Scoured River Bed Level using Groundsill

Definition

Groundsill is a river structure built across a river that aims to restore riverbed by reducing the speed of the water currents and increase the rate of sediment deposition in the upstream part of the groundsill. This is intended to secure the riverbed and hence the foundation of bridges or river structure that are upstream of the groundsill, so that building structures in the upper reaches of the river such as bridges or other water structures are safe against erosion.



Figure 3.93 Side elevation of a weir



Figure 3.94 Typical damaged groundsill

Scope of Works

It involves the restoration of the river bed to level. To raise the river bed, weir or ground sill is provided at the downstream of the damaged riverbed. The ground sill is the most appropriate method in restoring the river bed to its original level. However, it is necessary to design the scale of the ground sill in consideration with a hydrological study.

Required Materials, Tools/Equipment and Personnel

i. Required materials

- Concrete blocks or quarry stones reinforcement
- Coarse and fine aggregates
- Cement
- Water
- Rapid hardeners

ii. Required tools/equipment

- Excavator
- Concrete mixer
- Concrete vibrator
- Concrete pump
- Formwork
- Lorry

iii. Required personnel

Skilled personnel works trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Works Sequence

- i. Study and recommend locations for repair.
- ii. Observation of groundsill damage in the field

Observations of groundsill damage are carried out directly in the field to determine the development of groundsill damage from year to year using photo data from drone recordings. Groundsill damage can be observed using drone images.



Figure 3.95 Example of progressive groundsill damage based on field observations

Based on the results of direct observations in the field and photos of groundsill damage recorded by drones from the previous year, groundsill damage can be inventoried, both for the type of damage, damaged construction, the position of the damage, and the volume of damaged construction. All groundsill damage data is recorded and collected and will be used to determine the type and method of repairing the groundsill.

- iii. Design groundsill heights for safe function

Design should follow approved standards and be approved by the Engineer.

The existing groundsill planning data as built will be used as an initial guideline for repairing the groundsill damage.

- iv. Cofferdam installation

A cofferdam functions to drain river water from upstream to downstream so as not to interfere with the implementation of groundsill construction. The installation of the cofferdam shall conform to applicable standards and Engineer's approval can be as shown on Figure 3.96.

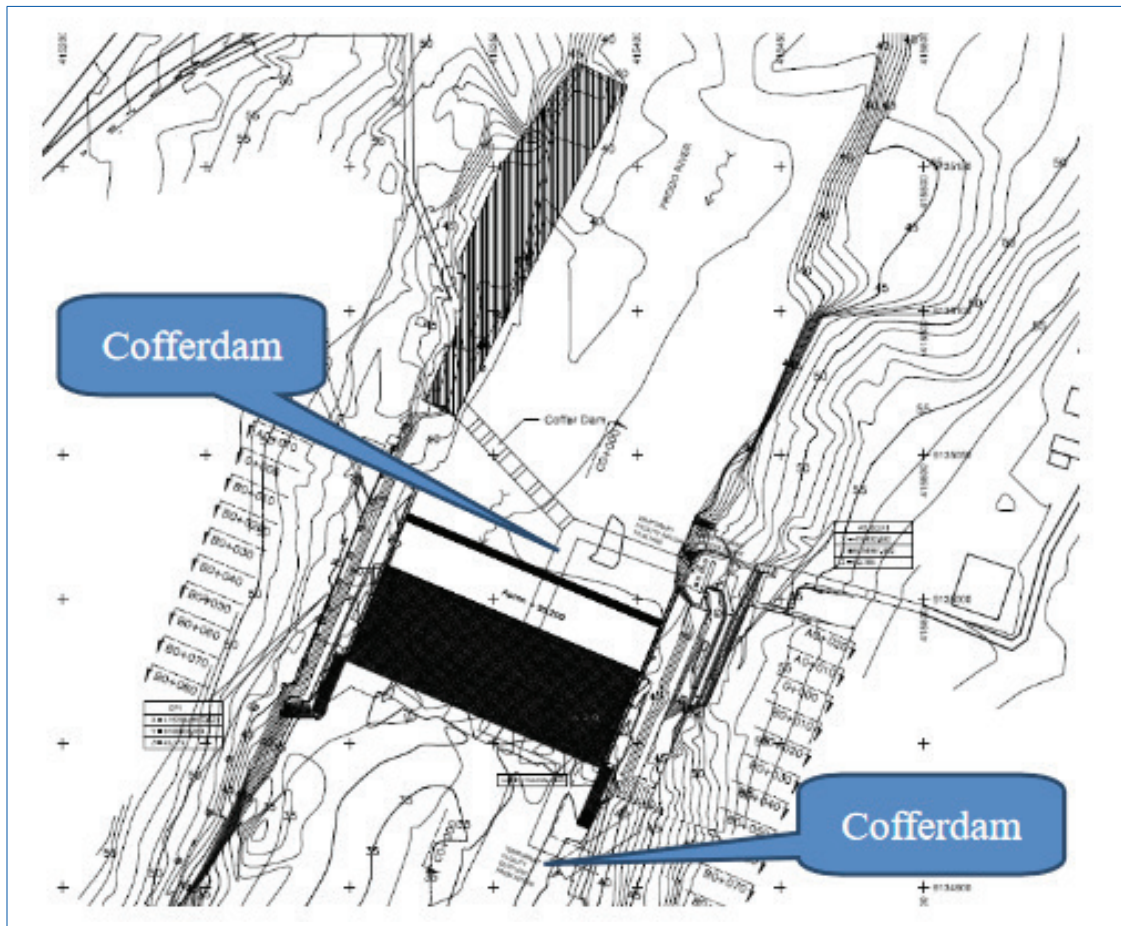


Figure 3.96 Cofferdam installation

- v. Execute the groundsill repair works

By studying the initial planning of the existing ground sill as built and based on the results of the ground sill damage inventory, it can be determined that the construction of the ground sill repair can consist of:

a. Repairing groundsill subgrade using class 15/20 concrete as blinding

The subgrade needs to be repaired because it will be the foundation of the ground sill concrete block.

The subgrade of the river bed area which was originally sand is replaced with class 15/20 concrete as blinding and the lock is in the form of steel sheet piles so that they are no longer eroded by the flow of the river.

b. Analysis of ground sill concrete blocks weighing 3.4 tons of class 30/20 concrete quality

The stability of the concrete block against dynamic water pressure will be checked using empirical formulas as per the guidelines for structural design of ground sill.

c. Arrangement of the groundsill downstream area

The new concrete blocks are installed on the damaged parts in line with the existing layout as built as at the time of construction.

vi. Concrete blocks movement

Concrete blocks are cast in the groundsill area for easy mobilization as shown on Figure 3.97. Concrete blocks using concrete weighing 3.4 tons and made of reinforced class 30/25 concrete and each concrete block is connected by reinforcement.

All existing concrete blocks must be moved downstream of the groundsill in such a way that sand miners cannot approach the area downstream of the groundsill.

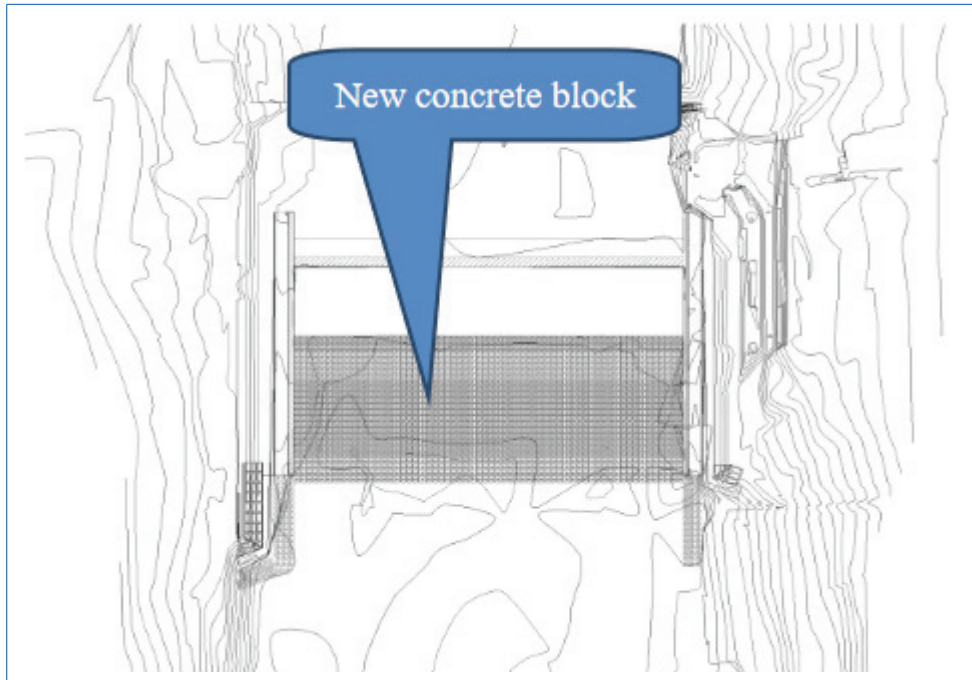


Figure 3.97 Layout concrete blocks

Monitoring and Evaluation

Monitoring of reinstated section by the Engineer.

Performance Test – Settlement checks and visual inspection.

Measurements and Payment

Measurement shall be in cubic meters (m^3).

Payment shall be full compensation for provision for all materials, equipment, labour, formwork and other related services necessary for reinstatement of river bed level as detailed in plans and specifications.

3.7 Under Water Repairs

3.7.1 Introduction

Underwater problems can be very complex to diagnose given that they are apparently not visible to the human eye. It is important that solutions to underwater problems are based on sound engineering. There is a tendency to make the solution fit one of a few common underwater repair techniques. A major concern is that the repair may only hide a structural problem while it continues to worsen, as is the case when pile jackets are installed in a marine environment without consideration of cathodic protection systems.

For example, when contaminated concrete and corroded reinforcing steel are left in place to interface with new concrete, the corrosion process actually accelerates. Consequently, covering a reinforced concrete member with a stay-in-place form or jacket will not stop or prevent further corrosion of the reinforcement. The member may look satisfactory while it is deteriorating to an unsafe condition.

Since most bridge engineers are not divers, it is important that they understand the problems and limitations in performing an underwater repair. All repairs above water are not cost effective when performed by divers in underwater conditions. It may be less expensive to accept that the deterioration will continue and modify the load path by designing the repair to support the total load or by designing a supplemental supporting system than to remove and replace the damage.

3.7.2 Underwater Repair Methods

3.7.2.1 Pressure Crack Sealing Underwater

Definition

Pressure injection can be used, within limits, against a hydraulic head provided the injection pressure is adjusted upward to counteract the pressure of the hydraulic head. The material must displace the water as it is injected into the crack to ensure that the crack is properly sealed resulting in a watertight monolithic structural bond.

Cracks expose the reinforcing steel to moisture, setting the stage for the corrosion process to begin. In saltwater environments, corrosion can occur very fast. Epoxy pressure injection has gained widespread acceptance as a cost-effective method to bond together and seal cracked structural concrete members.

Epoxies must have certain characteristics to cure and bond the cracked concrete together. Many adverse elements are present inside the concrete crack, such as water, contaminants carried by water, dissolved mineral salts, and debris from the rusting reinforcing steel.

The epoxy injection resins for cracks are formulated in low viscosity, and they do not shrink appreciably. The surface wet-ability of epoxy resin is of major importance, because the resin should displace all water in the crack and adhere to a wet surface and then cure in that environment.

Challenges to successful repair using this method include:

- i. Contaminants growing inside the crack, especially those found underwater, can reduce the successful welding of cracks.
- ii. Corrosion debris which can also reduce the effectiveness of pressure injection.
- iii. Injection is labour-intensive. As the temperature drops below 10°C, it becomes more difficult to pump the epoxies into fine cracks.
- iv. Inexperience on the part of the diver in injection and the formulation of the epoxy for injection.
- v. Lack of time and / or patience which is required for the successful injection repair.

Scope of Works

The scope of the procedure is to repair cracks saturated with water with proper selection of water-compatible adhesive, normally an epoxy resin, dormant (non-moving). The procedure can also repair other small voids such as delamination or honey-combed areas near the surface of the concrete.

Required Materials, Tools/Equipment and Personnel

- i. **Required materials**
 - Epoxy resin
 - Ready mixed Concrete
 - Concrete anti-washout admixtures (silica fume or fly ash)
- ii. **Required tools/equipment**
 - Mechanical grinders and scrubbers for cleaning concrete surfaces.
 - High-pressure water jets.
- iii. **Required personnel**

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

- i. Remove the salt-contaminated concrete and rust from contact with existing reinforcing steel to ensure that the corrosion damage will not continue (unless cathodic protection was used).

- ii. Clean the cracks using a high-pressure water system and shape the surface of the concrete directly above the crack so that it can be sealed with a grout.
- iii. Install injection ports in holes drilled to intersect the crack by a hydraulic or pneumatic drill.
- iv. Ensure that quality of epoxy mortar with anti-wash out admixture and accelerators meet the specified standards by manufacturers and as shall be directed by the Engineer.
- v. Pressure inject the adhesive into the crack through the ports that are embedded in the grout at regular intervals. The injection sequence begins at the bottom and advances upward. The injection moves up when the adhesive reaches and begins to flow from the port. Epoxy resin is mixed either before or after pumping. Cracks varying in width from 0.002 to 0.25 inches may be injected successfully.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance tests: Visual inspection using underwater cameras, consistency tests and Non-destructive tests.

Measurements and Payment

Measurement shall be in linear meters (m).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for underwater crack repair as detailed in plans and specifications.

3.7.2.2 Under Water Concrete Repairs

Definition

This method is intended for undertaking major under water repairs for concrete structures.

Required Materials, Tools/Equipment and Personnel

- i. **Required materials**
 - Pre-mixed concrete
 - Permeable concrete bags
 - Forms to encase damaged concrete or masonry substructure units
 - Polyethylene drainage pipe (used as form)
- ii. **Required Tool/Equipment**
 - Pile jacketing forms
 - Tremie Pipe
 - Concrete pump
 - Concrete cutter (hydraulic or pneumatic-powered concrete saws)
- iii. **Required personnel**

Skilled personnel trained by KIHBT and registered/accredited by NCA.

Preparation for Works

- Provide traffic warning signs,
- Identify and cordon work area,
- Prepare diversion/lane management.

Safety Considerations

- i. Provision of PPE's for the staff or labourers,
- ii. Implementation of safety regulations as per the traffic management plans,
- iii. Adhere to all environmental, occupational, safety and health regulations.

Work Sequence

i. Preparatory works

Identification of the repair locations, appropriate inventory to be undertaken and design to be done by the Engineer.

ii. Cleaning works

The surfaces to be repaired shall be well cleaned using mechanical means or any other applicable method.

iii. Encasing

Newly prepared surface can be encased with jacketing forms as form work as maybe required by the work item.

iv. Concrete preparation

Using anti-wash out admixtures, prepare concrete mix design with adequate strength and consistency required for works as approved by the Engineer.

v. Concrete placement

Appropriate methods as approved by the Engineer shall be used in the placement of the mixed concrete underwater with the help of divers and other underwater safety mechanisms.

vi. Quality assurance

Material quality, process and workmanship to conform to applicable repair standards for underwater works.

Monitoring and Evaluation

Monitoring of repaired section by the Engineer.

Performance tests – Visual inspection using underwater cameras, consistency tests and Non-destructive tests.

Measurements and Payment

Measurement shall be in cubic meters (m³).

Payment shall be full compensation for provision for all materials, equipment, labour, related services necessary for underwater concrete repairs as detailed in plans and specifications.

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