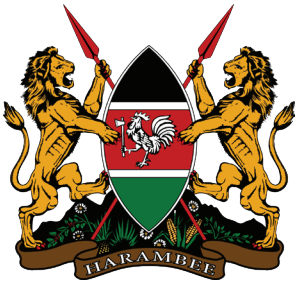

BRIDGE INSPECTION & REPAIR

TRAINING MATERIAL

February 2024

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

BRIDGE INSPECTION & REPAIR
TRAINING MATERIAL
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OVERVIEW OF BRIDGES IN KENYA AND BRIDGE ENGINEERING TERMINOLOGIES

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Introduction

- A bridge is a structure, that can be accessed by any traffic, with the function of aiding crossing over a waterway, road or any other obstacle. It also includes box culverts, pipe culverts and tunnels.

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2. Bridge Engineering Terminologies

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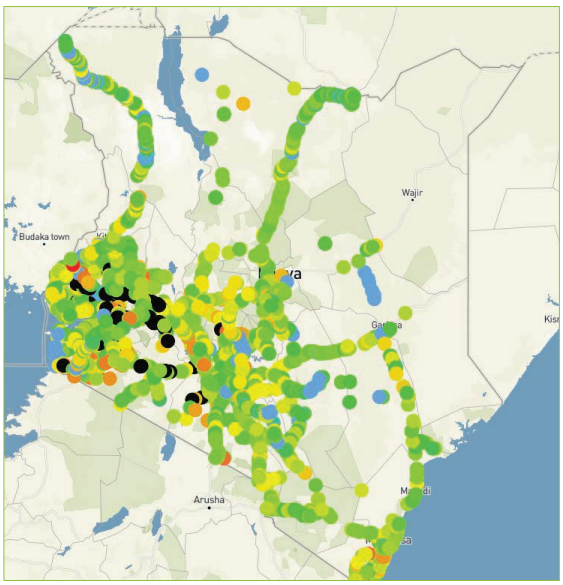
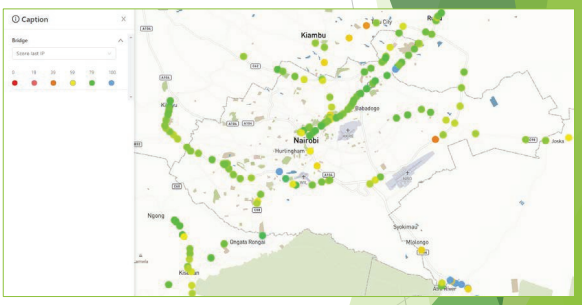
1. Overview of Bridges in Kenya



Nairobi Region



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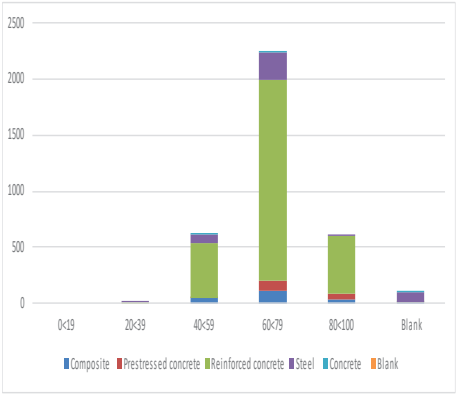
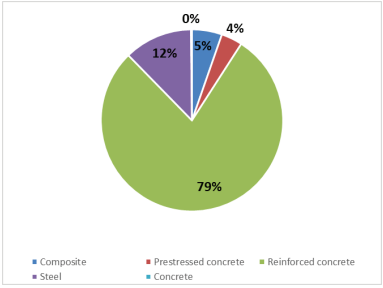
1. Overview of Bridges in Kenya

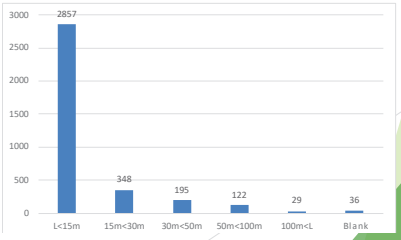
Damage level



Main material



Bridge length



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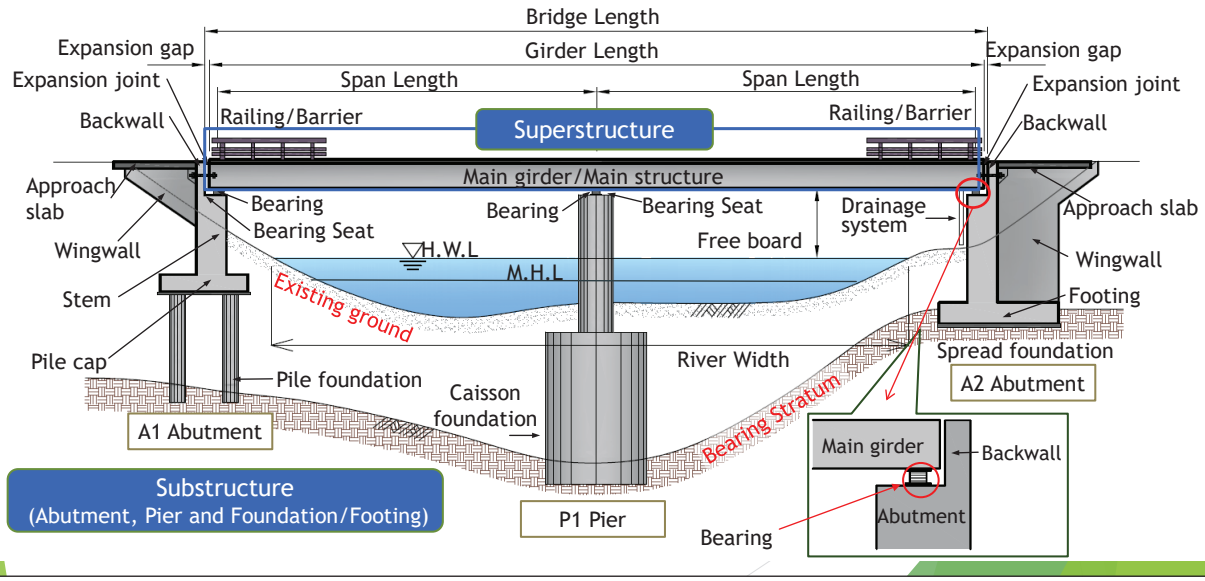
2. Bridge Engineering Terminologies

(1) Bridge components



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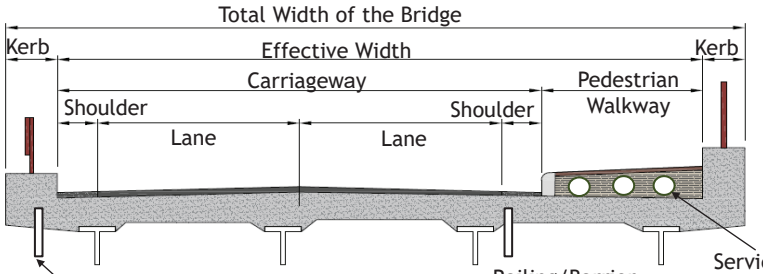
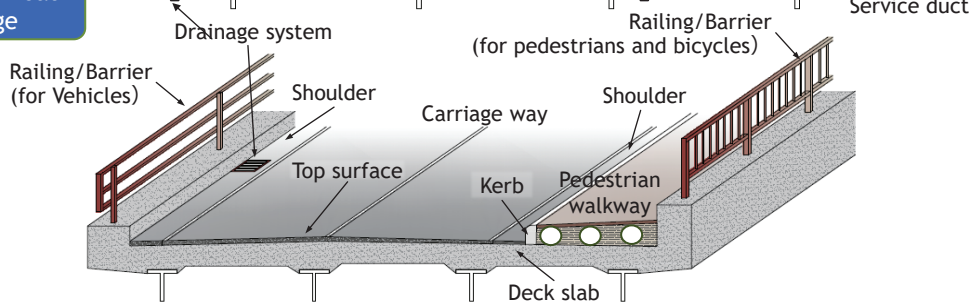
2. Bridge Engineering Terminologies

Cross Section



Structure of Road on Bridge



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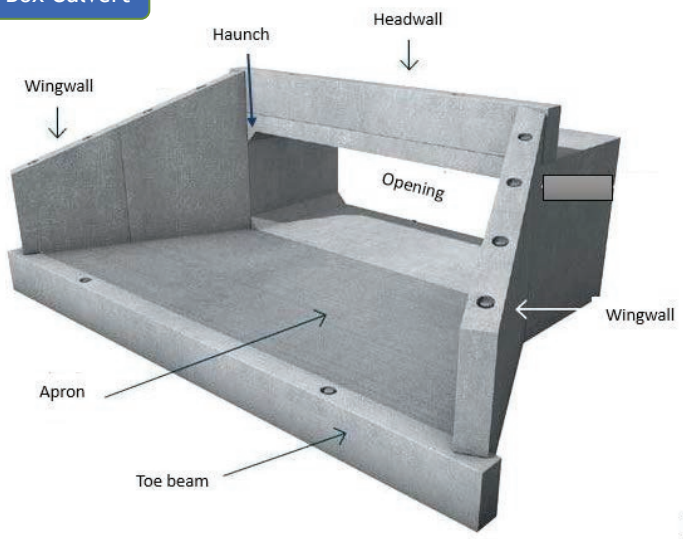
2. Bridge Engineering Terminologies

Structure of a Box Culvert



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2. Bridge Engineering Terminologies

Term	Explanation
SUPERSTRUCTURE	Part of a bridge that supports the weight of objects passing through the bridge and transmits it to the substructure. It consists of the girder(s), deck, cross beam(s), lateral bracing(s), diaphragm(s) etc.
a) Deck	A structural member that directly supports vehicles, pedestrians, etc. passing through a bridge and transmits the load to the main girder.
b) Girder	The main part of the superstructure that supports all the loads acting on the bridge deck. In general, it is called main girder in the case of girder structure, and main structure in the case of truss or arch structure, etc.

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2. Bridge Engineering Terminologies

Term	Explanation
Ancillary Members	These are structural elements that aid smooth functioning of the bridge, they include the Expansion Joints, Bearings, and Approach Slab
a) 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 deck. It is mainly made of steel or rubber.
b) Bearing	A device for transmitting forces from the superstructure to the substructure.

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2. Bridge Engineering Terminologies

Term	Explanation
c) Approach Slab	A concrete slab installed behind the abutment to prevent elevation difference from occurring because the fill material behind the abutment settles due to inadequate compaction.
SUBSTRUCTURE	Structural members that transfer the load from the superstructure to the ground through the bearings. It is a general term for bridge abutments, piers and foundations.
a) Abutment	Structural member located at the ends of a bridge connecting the embankment portion of the approach road to the bridge. It supports the load from the superstructure and prevents the lateral pressure from the backfill material.

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2. Bridge Engineering Terminologies

Term	Explanation
b) Pier	A structural member that transmits the load from the superstructure to the foundation. It divides the bridge into spans
c) Foundation	The part of the substructure that is in contact with the ground. Depending on the form, there are different types of foundations such as spread footing, pile foundations, and caisson foundations, etc.

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2. Bridge Engineering Terminologies

Term	Explanation
NON-STRUCTURAL MEMBERS	Elements such as drainage facilities, road restrain systems which perform non-structural functions on a bridge
a) Road Restrain System	A structure designed to prevent vehicles and pedestrians passing over a bridge from falling off the bridge. They include the Guardrails, Crush Barriers *et cetera*.
b) Drainage facility	Is installed to drain water from the bridge surface. It consists of a drainage basin and a drainage pipe.

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2. Bridge Engineering Terminologies

Term	Explanation
Backwall	The primary component of the abutment acting as a retaining structure at each approach.
Expansion gap	A gap provided to allow for expansion and contraction due to temperature changes. It is provided between a bridge girder and abutment or between girders that are not continuous.
Bearing seat	A place where bearings are installed.

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2. Bridge Engineering Terminologies

Term	Explanation
Bridge length	The total length of the bridge. That is, the distance between the front of the backwall of the abutments.
Span length	The distance between two support bearings.
Girder length	Length of the main girder.
H.W.L	The planned High Water Level assumed in the design.
M.H.L	The arithmetic mean of the high water heights observed.
Free board	Height between the bottom edge of the superstructure and the H.W.L.

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References

- Information on slide 2 refer to Bridge Inspection Manual for ARBICS & PBC page 13.
- Information on slides 4 & 5, the data was obtained from KeNHA Bridge Management System.
- Information on slides 6, 7 & 8, refer to Inspection Manual for Bridges pages 23 & 24.
- Information on slides 9-15, refer to Inspection Manual for Bridges pages 25-27.

02-
CLASSIFICATION OF BRIDGES AND FUNCTIONS OF BRIDGE COMPONENTS

1

CONTENTS

1. Classification of Bridges
2. Functions of various bridge elements

2

1. Classification of Bridges

Bridges are classified considering the following aspects:

(a) Classification by usage

(b) Classification by the material used

(c) Classification by the support method

(d) Classification by deck position

(e) Classification by bridge plan shape

(f) Classification by structure type

(g) Classification by bridge position/grade separation

3

1. Classification of Bridges

(a) Classification by usage

Use	Explanation
Road bridge	A structure forming a section of the road that is used for vehicular traffic.
Railway bridge	A structure constructed for the exclusive purpose of carrying railroad traffic across an obstruction.
Pedestrian bridge	A structure used for pedestrians only, also known as footbridge
Aqueduct bridge	A structure used as the waterways for water supply, hydropower generation, irrigation, etc.
Combined bridge	A structure that combines the functions of a road and a railway, a road and a waterway, etc.

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1. Classification of Bridges

(a) Classification by usage cont…

Pedestrian bridge

Railway bridge

Road bridge

Aqueduct bridge

Combined bridge

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1. Classification of Bridges

(b) Classification by material used

Material	Explanation
Timber bridge	Bridges made of wood
Masonry bridge	Bridges made of masonry blocks and bricks
Concrete bridge	A bridge principally made of reinforced concrete or pre-stressed concrete.
Steel bridge	Bridges whose superstructure is made of steel
Composite material bridge	A bridge whose superstructure is made of steel and concrete.

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1. Classification of Bridges

(b) Classification by material used cont…

Timber bridge

Masonry bridge

Concrete bridge

Steel bridge

Composite material bridge

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1. Classification of Bridges

(c) Classification by support method

i) Simply supported bridge

Bridge girders are simply supported at each span. Statically determinate structure.

ii) Continuous bridge

Bridge girders are continuous across two or more spans with three or more supports. Statically indeterminate structure.

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1. Classification of Bridges

(c) Classification by Support Method cont...

Simply Supported Bridge
Nguutani bridge Along A3

9

1. Classification of Bridges

(c) Classification by Support Method cont...

Continuous Bridge
Athi River Bridge along Namanga Road

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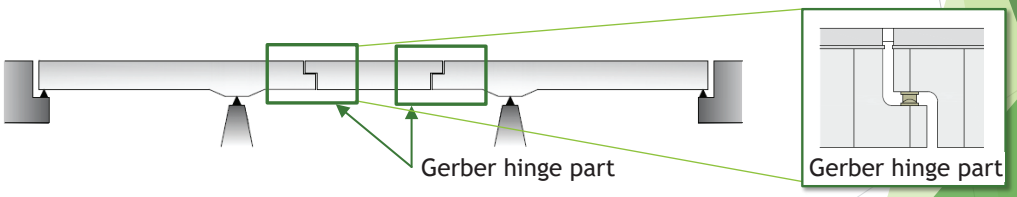
1. Classification of Bridges

(c) Classification by support method cont…

iii) Cantilever/Gerber bridge

Bridges with hinges installed at appropriate places in a continuous girder bridge to create a statically determinate structure.



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1. Classification of Bridges

(c) Classification by Support Method cont...

Cantilever/ Gerber Bridge
Tana River Bridge Garissa Along A3

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1. Classification of Bridges

(d) Classification by deck position

i) Deck bridge

A bridge with a deck on top of the girders. Girder bridge in general is classified as deck bridge.

ii) Half-through bridge

A bridge with a system of upstand girders.

Left: Half-through bridge Right: Deck bridge

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3. Classification of Bridges

(d) Classification by deck position cont…

iii) Through bridge:

A bridge with the deck under the superstructure.

iv) Double deck bridge:

Bridge with two decks of either a road or railway and so on.

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1. Classification of Bridges

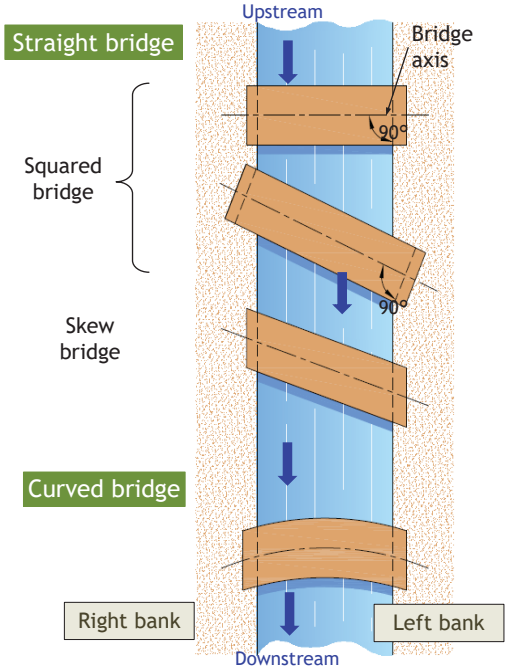
(e) Classification by bridge alignment

i) Straight bridge is a bridge with a straight axis.

ii) Squared bridge is a kind of straight bridge, and the bearing line of the bridge girder is right angle to the bridge axis.

iii) Skew bridge is also a kind of straight bridge, and the bearing line of the bridge girder is oblique to the bridge axis.

iv) Curved bridge is a bridge with a curved bridge axis.



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1. Classification of Bridges

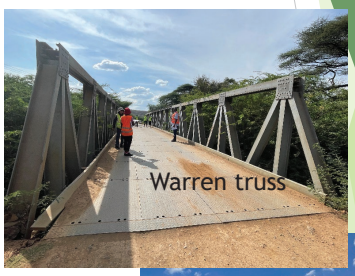
(f) Classification by structure type

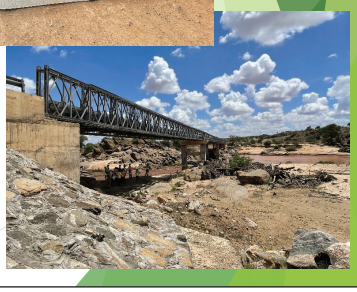
i) Girder bridge

Beam girder

Box girder

ii) Truss bridge





Lattice truss

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1. Classification of Bridges

(f) Classification by structure type cont…

iii) Arch bridge

Left: Half-through bridge Right: Deck bridge

iv) Rigid frame

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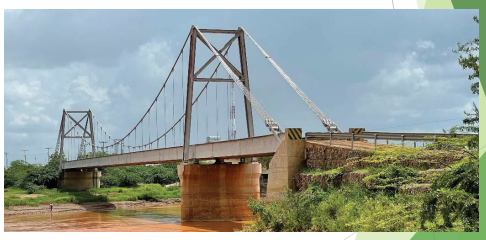
1. Classification of Bridges

(f) Classification by structure type cont…

v) Cable stayed bridge

vi) Suspension bridge



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1. Classification of Bridges

(g) Classification by bridge position/ grade separation

Location	Explanation
Overpass	Bridges over a multi-level intersection.
Underpass	Bridge/Road under a multi-level intersection.
Viaduct	Multi-short span connected bridges that cross or mountainous areas.

Overpass

Underpass

Viaduct

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2. Functions of various bridge components

Main bridge components

1) Superstructure
2) Substructure
3) Ancillary members

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2. Functions of Bridge Components

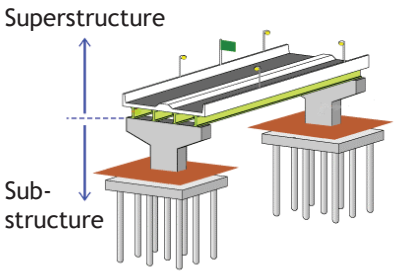
Role of the members of the bridge

1) Superstructure

Support the weight of objects passing through the bridge and transmits it to the substructure. They include; girders, deck and slab.

2) Substructure

A structure that transmits the load transmitted from the superstructure to the supporting ground. They include; abutments, piers and foundation.



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2. Functions of Bridge Components

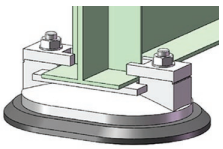
3) Ancillary members

i) Bearing

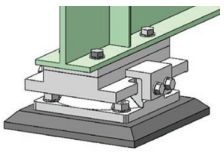
A component placed in between the superstructure and the substructure to transmit the forces from the superstructure to the substructure. A bearing has four main functions;

- To support vertical loads,
- To support horizontal loads,
- To allow movement in the horizontal direction,
- To allow the rotation/bending of the main girder.

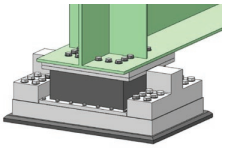
Generally, there are different types of bearings as shown in the images.



a) Fixed bearing



b) Movable bearing



c) Horizontal force dispersing bearing

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2. Functions of Bridge Components

3) Ancillary members

i) Bearing cont…

a. Fixed bearing

Absorbs only the rotational displacement of the superstructure. In addition to vertical loads, horizontal loads due to earthquakes and wind are also supported by the bearing.

b. Movable bearing

Absorbs rotation and expansion/contraction of the superstructure. Supports only vertical load, no horizontal load.

*Both photos on the right were taken from River Mbagathi Bridge, near Nairobi.

Bearings at the abutment fixed by anchor bolt.

Movable bearings at the pier. Not fixed.

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2. Functions of Bridge Components

3) Ancillary members

i) Bearing cont…

c. Horizontal force dispersing bearing

A bearing that is elastically fixed and is generally made of laminated rubber. Not rubber pad only.

The most common types of bearings are fixed and movable bearings. However, when seismic forces act on a bridge, fixed bearings subjected to seismic forces cause a lot of damage to the substructure.

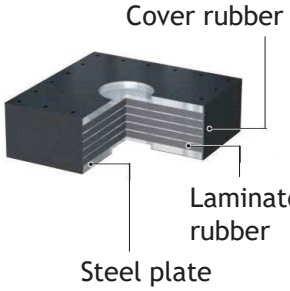

Fig. Structural interior of horizontal force dispersing bearing

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2. Functions of Bridge Components

3) Ancillary members

i) Bearing cont…

Sample photos of bearings.

Sliding steel bearing used on Kilifi Bridge

Roller steel bearing used on Nyali Bridge

Elastomeric bearing used on Mbita Bridge

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2. Functions of Bridge Components

3) Ancillary members

ii) Expansion Joint

It is a device installed at the expansion gap 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.

NOTE:

Water and debris tend to accumulate around bearings and expansion joints. In order for these devices to function properly, it is important to clean them and keep them in a sound condition as part of bridge maintenance.

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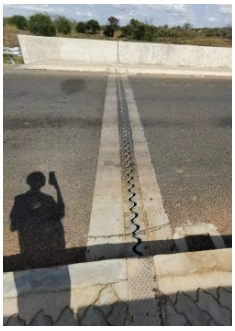
2. Functions of Bridge Components

3) Ancillary members

ii) Expansion Joint cont…

Sample photos of expansion joints

Expansion joint on Bridge near Marsabit on A2 Marsabit - Turbi



Expansion joint on Tiva Bridge Reliever

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2. Functions of Bridge Components

3) Ancillary members

iii) Approach slab

A concrete slab installed behind the abutment to prevent elevation difference from occurring because the fill material behind the abutment settles due to inadequate compaction.

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References

- Information on slides 3-19, refer to Inspection Manual for Bridges pages 37-34.

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03-
BASIC KNOWLEDGE FOR BRIDGE DESIGN

1

CONTENTS

1. Design load
2. Behavior of a member under load
3. Characteristics of steel members
4. Characteristics of concrete members
5. Reinforced concrete structures
6. Pre-stressed concrete structures
7. Steel structures
8. Connection methods of steel structures

2

1. Design load

Self-weight, traffic load, and natural phenomena that affect structures are indicated as loads in the design and are applied to the structure.

The components of a load include the direction (direction of action), the position of load, and the magnitude and shape of the distribution to be applied.

Bridge Engineers should have the ability to conceptualize the kind of forces to be loaded on a bridge.

3

1. Design load

- Type of loads

Primary Loads

Loads that must be considered when designing the main structural components of a bridge.

These are:
Self weight (dead load), traffic load (live load), earth pressure and water pressure.

Secondary Loads

Loads that do not necessarily act constantly but must be taken into account when designing the main structural components of a bridge.

E.g. wind load, seismic load, loads due to temperature changes/variations (thermal loads), etc.

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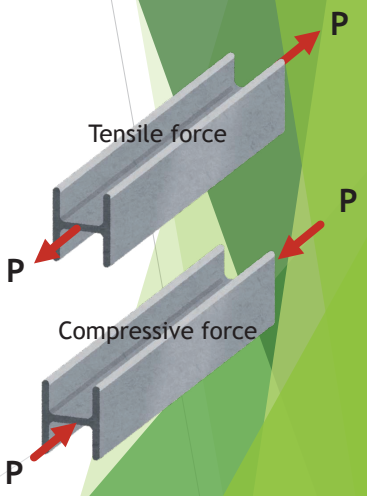
2. Behavior of a member under load

Forces acting on the cross-section of a member and the behavior of the member

(1) Axial Force

- Force that acts in the direction of the axis of a member; it can either be tensile or compressive.
- The force per unit area is called tensile stress or compressive stress.
- Steel members are designed not to yield or rupture under load.
- Concrete members are designed not to fail (crush or buckle) under compression. (The tensile strength of concrete is not considered in the design)



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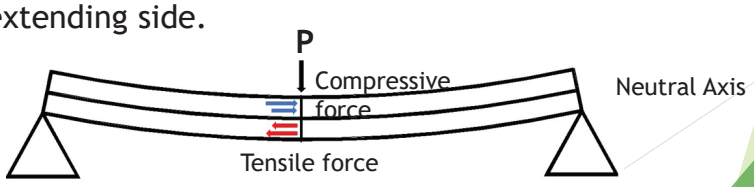
2. Behavior of a member under load

(2) Bending Moment

- When a member is bent as shown in the figure below, the member flexes and each cross section rotates.
- The force that causes the member to bend and the cross-section to rotate is called “Bending Moment”.
- As the cross section rotates and flexes, compressive stress along the axial direction is generated on the shrinking side, and tensile stress along the axial direction is generated on the extending side.



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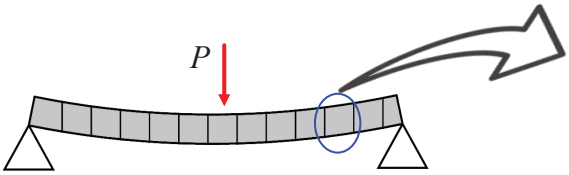
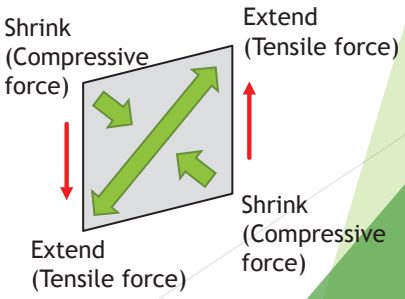
2. Behavior of a member under load

(3) Shear Force

- A force which results from equal but opposite transverse forces, which tend to slide one section of a member past an adjacent section causing slippage deformation.
- Bending moment and shear force calculations are essential while designing any structural members.





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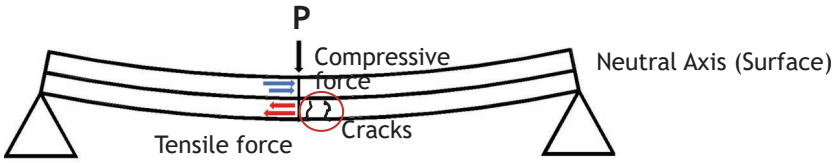
2. Behavior of a member under load

(4) Crack directions under bending moment

- Cracks occur in the direction perpendicular to the direction of the tensile force.



Under bending moment

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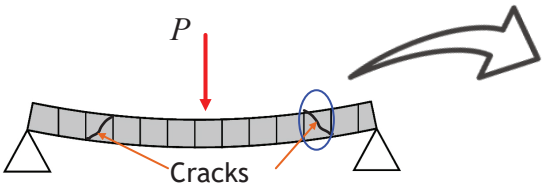
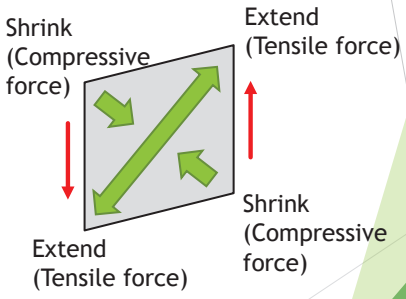
2. Behavior of a member under load

(5) Crack directions under shear force

- Cracks occur in the direction perpendicular to the direction of the tensile force.



Under shear force



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2. Behavior of a member under load

Terms related to mechanical properties

Term	Explanation
Elastic deformation	Elastic deformation is the reversible distortion of a material. A member is elastically deformed if it returns to its original shape upon removal of a force. Bridges are designed to deform elastically and return to their original shape after the live loads are remove.
Plastic deformation	Plastic deformation is the irreversible or permanent distortion of a material. A material is plastically deformed if it retains a deformed shape even after removal of a force. Plastic strain is sometimes referred to as irreversible or permanent strain because it remains even after the stress is removed.

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2. Behavior of a member under load

Terms related to mechanical properties cont…

Term	Explanation
Yield	Yield is the change from an elastic state to a plastic state due to an increase in external force. The ability of a material to resist plastic (permanent) deformation is called the yield strength.
Toughness	Toughness is the energy required to break a material and this is not necessarily related to strength.
Fatigue	Fatigue is a material response that describes the tendency of a material to break when subjected to repeated loading. Fatigue failure occurs within the elastic range of a material after a certain number and magnitude of stress cycles have been applied.

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2. Behavior of a member under load

Terms related to mechanical properties

Term	Explanation
Strain hardening	When a structure deforms plastically, the resistance to deformation increases as the degree of deformation increases.
Modulus of elasticity	A coefficient that expresses the relationship between stress and strain that occurs when stress within the elastic limit is applied to an elastic body.

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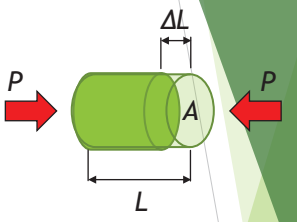
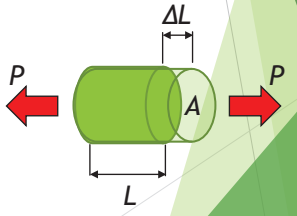
2. Behavior of a member under load

Relationship between stress and strain

- Stress (σ) is the load (P) divided by the cross-sectional area (A)
  $\sigma = P/A$
- Strain (ε) is a dimensionless quantity calculated by dividing the deformation (ΔL) by the original member length (L)
  $\varepsilon = \Delta L/L$
- The relationship between stress and strain, using the modulus of elasticity (E), is as follows
  $\sigma = E \cdot \varepsilon$



(a) Compressive Stress



(b) Tensile Stress

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3. Characteristics of a steel material

- Steel has high tensile strength and high ductility than most construction materials. It can be processed into steel plates of various shapes, which are used alone or in combination to make components.
- Mechanical properties such as hardness, strength, and tenacity can be adjusted by adding various elements during steelmaking and heat treatment to compensate for defects.
- Steel has a density ranging between 7500kg/m^3 to 8000kg/m^3

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3. Characteristics of a steel material

Properties of steel

Tensile strength

- Tensile strength is defined as the measure of the force required to break a steel material. The tensile strength of steel is almost as high, which makes it relatively impervious to crack or break, which is important for its use in the construction of structures.

Hardness

- Hardness is defined as the ability of steel to withstand friction and abrasion of the material and is a measure of how durable it is. It is the most poorly defined material property because it can indicate resistance to scratching, resistance to abrasion, resistance to indentation or shaping, or resistance to localized plastic deformation

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3. Characteristics of a steel material

Properties of steel cont…

Yield Strength

- Yield strength refers to the measure of the force required to initiate deformation of a steel material. It helps in choosing the suitable material for construction based on the requirement.

Ductility

- It is capacity to change shape under the influence of force applied in such a way that the material does not crack. This is one of the most important mechanical properties of steel.

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3. Characteristics of a steel material

Properties of steel cont…

Toughness

- Is the ability of a material to absorb energy without fracturing or breaking. In simple term, it is the resistance of a material to fracture when subjected to stresses. It depends heavily on strength and flexibility.

Malleability

- It is the property of a steel to moulded into thin sheets and take a different shape without breaking.

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4. Characteristics of concrete member

- Concrete is a composite material consisting of coarse and fine aggregate grains bonded together with cement paste.
- The paste, which is as binder material, gradually develops strength through the hydration of the cement.
- Therefore, the quality of concrete depends not only on the properties of individual constituent materials such as cement paste and aggregate, but also on the composite properties of these materials and mix proportion.
- The composite properties are influenced by the conditions of construction and curing, as well as by the age of the materials.
- Concrete has a density ranging between 2400kg/m^3 to 2500kg/m^3

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4. Characteristics of concrete member

(1) Strength of Concrete

The strength of concrete is expressed by its **compressive strength.** Concrete class/ grade is an indication of the strength (N/mm^2) that concrete attains maturity at 28 days.

- The compressive strength is significantly greater than other strengths, and this is also used effectively in the design of reinforced concrete members.
- From the compressive strength, other strengths (tensile strength, shear strength) and properties of the hardened concrete can be roughly estimated.

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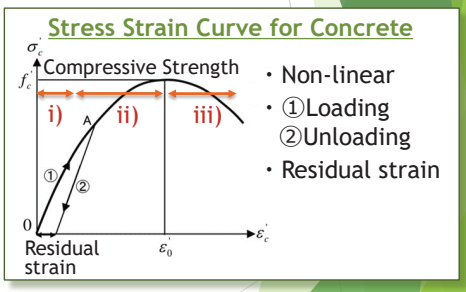
4. Characteristics of concrete members

(2) Elastic-plastic properties of Concrete (Stress-Strain Curve)

Stress-strain curves from compressive strength tests of concrete are divided into the following three portions:

i. Portion that can be regarded as a straight line
ii. Curved portion with increasing curvature until the maximum stress level is reached
iii. The part of the curve where the stress level gradually decreases as the strain increases, and then rapidly reaches failure



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4. Characteristics of concrete members

Concrete generates residual strain when the load is removed. The ratio to the total strain is smaller at lower stress levels and is about 10% at stresses of about 50% of the breaking strength.

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5. Reinforced concrete structures

Concrete: Resistant to compressive forces, but not to tensile forces.
Tensile force ≈ 0.1 x Compressive force

Steel: Resistant to compressive forces and tensile forces.

Leveraging each other's advantages

Reinforced Concrete
The tensile side of a concrete member is reinforced with steel bars.

Reinforced concrete structures are structures that allow for cracking.

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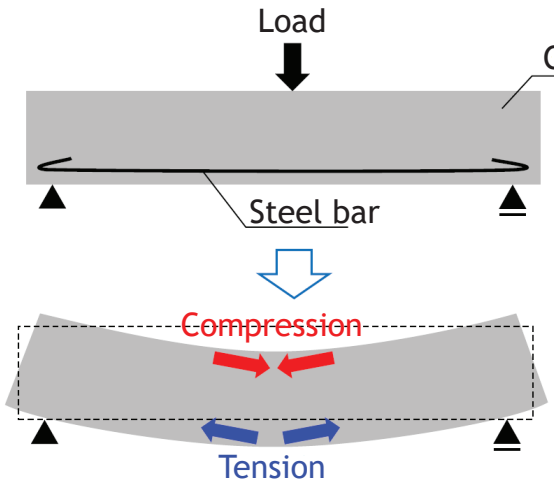
5. Reinforced concrete structures



In consideration of the deformation of a beam,

the upper side of the beam contracts (compressive force) and the lower side stretches (tensile force).

Therefore, steel bars are placed in the lower side where tensile forces occur to resist the tensile forces.

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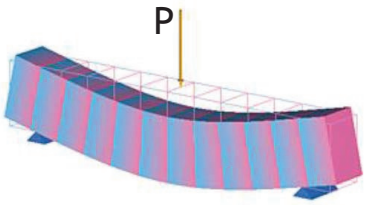
5. Reinforced concrete structures

Reinforced Concrete Structure

- A structure that resists bending moments by, combining concrete that is strong in compression, and steel that is strong in tension.
- Concrete resists in the compression area and steel bars resist in the tension area during bending.
- Tension strength of concrete is not considered in design.



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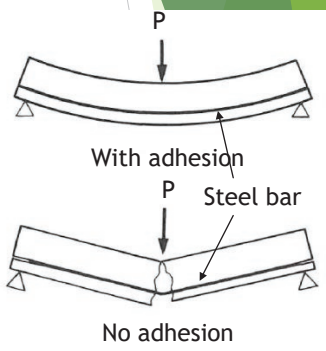
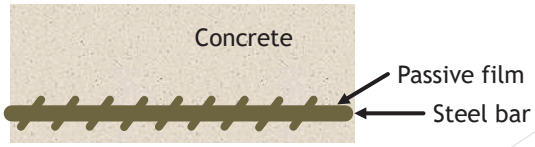
5. Reinforced concrete structures

1) Reasons for use of reinforced concrete structures

- Concrete is strong in compression, and steel is strong in tension thus they complement each other.
- Concrete is a strong alkaline, so the steel bars inside the concrete structure are resistant to rust because they are covered by a passive film.
- There is adhesion between concrete and steel bars.
- Coefficient of linear expansion of concrete and steel is almost equal. ($1.0 \times 10^{-5}(1/℃)$)





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5. Reinforced concrete structures

2) Merits and demerits of reinforced concrete structures

Merits:

- High fire resistance (Concrete is non-combustible)
- High durability (Lifespan is 50-100 years)
- Excellent in formability

Demerits:

- Large self-weight
- Poor workmanship affects the strength and maintainability
- High cost of construction since formwork is required

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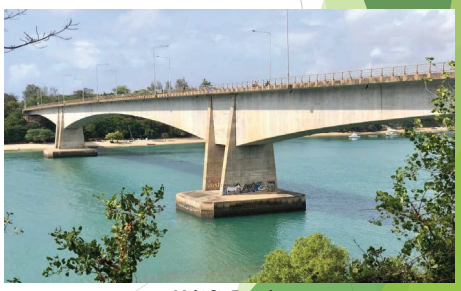
6. Pre-stressed concrete structures

A pre-stressed concrete structure is a structures to which compressive stress (pre-stressing) has been applied in advance to the cross-sectional area on the tensile side.

Examples of pre-stressed concrete structures

Nyali Bridge



Kilifi Bridge

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6. Pre-stressed concrete structures cont…

1) Merits and demerits of pre-stressed concrete structures

Merits:

- Able to build structures with minimum risk of cracking,
- Smaller cross-sectional dimensions and lighter weight,
- Compressive stress acts on the entire cross-section of the concrete at the serviceability limit state (effective for the entire cross-section),
- In the ultimate limit state, there is resilience even if some cracks occur.

Demerits:

- Uneconomical for short span structures,
- There are many cases to consider in design, and many complicated works in construction compared to RC structures.

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6. Pre-stressed concrete structures cont…

2) Classification of pre-stressed concrete structures

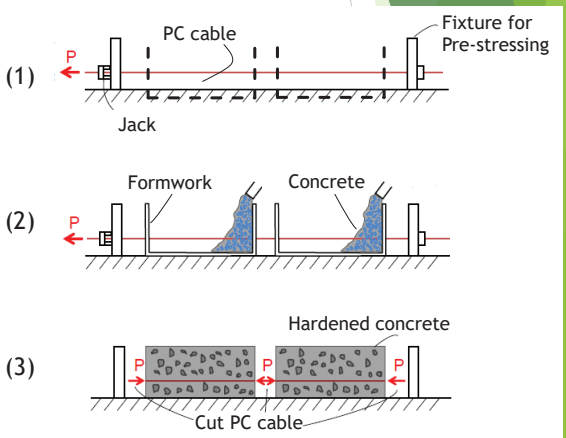
a) By the time of stressing

➢ Pre-tensioning

(1) Tension the PC cable in advance.

(2) After fixing the formwork, pour concrete material.

(3) Cut the PC cable after the concrete has hardened, then the concrete is pre-stressed by the adhesion between PC cable and concrete.



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6. Pre-stressed concrete structures

2) Classification of pre-stressed concrete structures cont…

Picture showing Pre-tensioning Method

*The photos above were taken at Mombasa Port Area Road Development (MPARD) Project Lot 2 construction site in Mombasa.

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6. Pre-stressed concrete structures

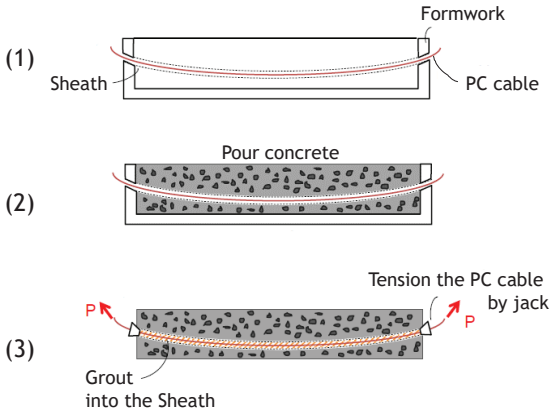
2) Classification of pre-stressed concrete structures cont...

➢ Post-tensioning

(1) Place the sheath at the designed location. The timing of inserting of the PC cable depends on the site condition.

(2) Pour concrete.

(3) After concrete has hardened, remove the formwork, tension the PC cable by jacking. Then pump grout into the sheath.



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6. Pre-stressed concrete structures

2) Classification of pre-stressed concrete structures cont...

Picture showing Post-tensioning Method

Before casting concrete

Tensioning work after the concrete hardens

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6. Pre-stressed concrete structures

2) Classification of pre-stressed concrete structures cont...

b) By structure type (amount of prestressing)

- Full prestressing

  Prestressing so that the combined stress on the tensile side is zero (Effective for all cross sections).

- Partial prestressing

  By adjustment of prestressing, tensile stress is allowable to occur to the extent that cracking does not occur, or cracking is allowed, but the crack width shall be kept below the limit.

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6. Pre-stressed concrete structures

2) Classification of pre-stressed concrete structures cont...

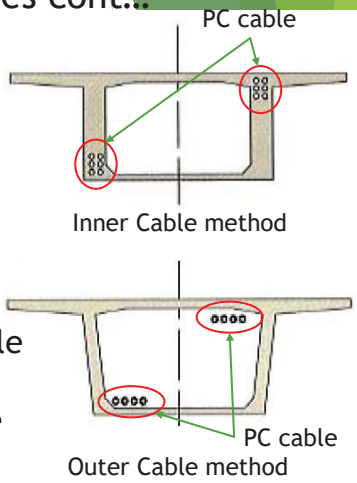
c) By PC cable location

- Inner cable method

  Place the PC cable inside of concrete member.

- Outer cable method

  Place the PC cable outside of concrete member [Advantage on the maintenance aspect]
  - The cross section can be thinner than inner cable method, then self-weight will be reduced.
  - Maintenance work will be easier since the cable can be seen and approached.
  - Applicable to reinforcement work of concrete member.



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7. Steel structures

(1) Characteristics of steel structures

Steel structure members are generally slender than concrete structures of the same span/ height.

The design must consider that **buckling** does not occur.

What's Buckling?

Imagine pushing on a straw – if you push gently, nothing really happens, but once you push it with enough force, it will bow outward at the center. This phenomenon is **buckling**. It is a different structural response than normal (in-plane) compression.

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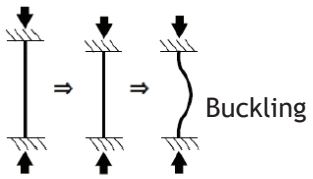
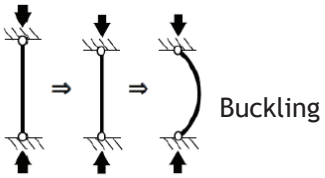
7. Steel structure

2) Buckling

- Buckling is the sudden change in shape (deformation) of a structural component under load, such as the bowing of a column under compression or the wrinkling of a plate under shear.
- The longer the member is, the more likely it is to buckle.
- The buckling susceptibility also depends on the fixation conditions at the end of the element.



Case-A: Fixed both ends



Case-B: Pin connection both ends

- Buckling is also more likely to occur when eccentric loading is applied.

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7. Steel structure

2) Buckling cont…

Types of buckling

There are two main types of buckling

i. Global buckling

This type of buckling where the axis of a structural member changes, the strength of the whole member is reduced.

ii. Local buckling

In this axis of structural member does not change, because it happens on a specific part of Colum or web of beams, but the strength beam or column cross section is reduced by the buckling of a component of that structural member.

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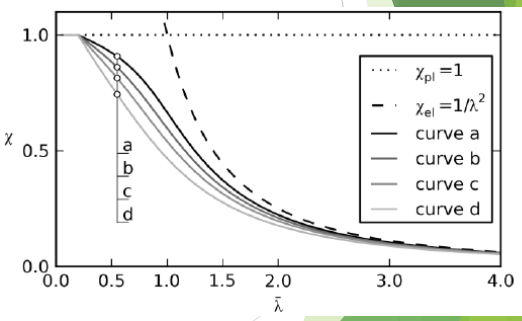
7. Steel structure

3) Design for Prevention of Buckling

The formula derived by Euler for long slender columns is given below;

$$F = \frac{\pi^2 EI}{(KL)^2}$$

F: Maximum or critical force (axial load on member).
E: Modulus of elasticity.
I: Smallest area moment of inertia (second moment of area) of the cross section of the member.
L: Unsupported length of member.
K: Member effective length factor, whose value depends on the conditions of end support of the column, as follows:



Reference: Eurocode 3

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7. Steel structure

3) Design for Prevention of Buckling

$$F = \frac{\pi^2 EI}{(KL)^2}$$

KL is the effective length of the member.

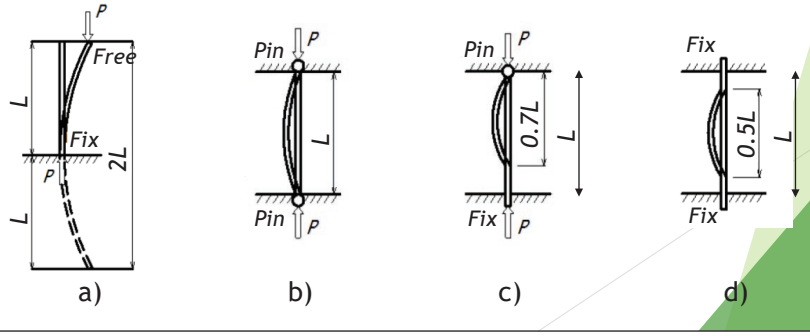
K: Member effective length factor,

a) For one end fixed and the other end free to move laterally, K=2.0.

b) For both ends pinned (hinged, free to rotate), K=1.0.

c) For one end fixed and the other end pinned, K=0.7.

d) For both ends fixed, K=0.5.



a) b) c) d)

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7. Steel structure

3) Design for Prevention of Buckling cont…

$$\sigma = \frac{F}{A} = \frac{\pi^2 E}{(l/r)^2}$$

where,

σ = F/A **-** the stress that causes buckling of the member,

l/r- is the slenderness ratio.

r- is the radius of gyration and can be obtained by the following formula:

$$r = \sqrt{I/A}$$

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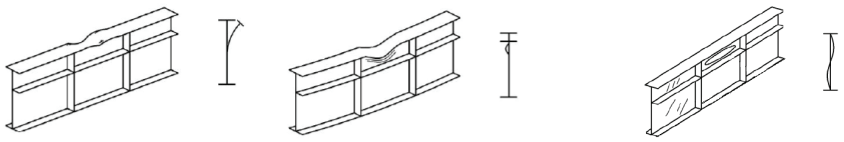
7. Steel structure

3) Design for Prevention of Buckling cont…

In sections where bending moments predominate and compressive forces occur, the design should be such that buckling phenomena does not occur.

During bridge inspection, the inspector shall check for deformation as shown in the figures below.



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7. Steel structure

4) Connection between steel members

There are three joint connection methods between steel members:

i. Welded joint
ii. High strength bolted connection
iii. Rivet connection (used in the past)

Welded joints require a higher level of technical skill and are performed by **qualified welding experts** compared to bolted connections.

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7. Steel structure

4) Connection between steel members cont…

i. Welded Joint

- The weld zone becomes a stress concentration zone and is a starting point for fatigue cracking.
- Since the risk of fatigue crack initiation increases, adequate control of weld quality is necessary.
- Depending on the shape of the weld, it can be classified as fillet welding, full penetration welding or partial penetration welding

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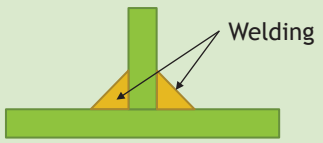
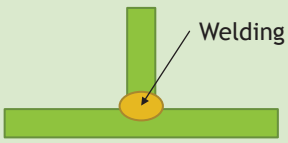
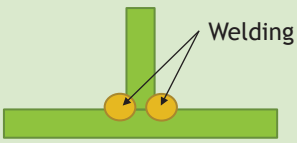
7. Steel structure

4) Connection between steel members cont…

i. Welded Joint

Fillet welding	Full penetration welding	Partial penetration welding
		
A welding method in which triangular-shaped weld metal is applied to the corner angles formed by the pieces of material to be joined.	A welding method in which the weld metal is fully integrated into the entire thickness of the joint. Butt weld is a type of full penetration welding.	A welding method in which the weld metal is partially integrated into the thickness of the joint.

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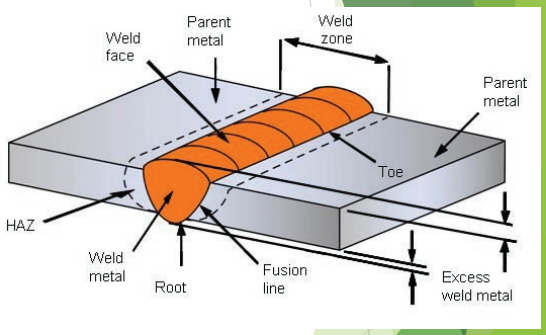
7. Steel structure

4) Connection between steel members cont…

Full penetration welding

Butt Weld

- A butt weld is a type of full penetration weld, it is one of the simplest and versatile types of weld joint designs.
- The joint is formed simply by placing two pieces of metal end-to-end and then welding along the join.



- Importantly, in a butt joint, the surfaces of the workpieces being joined are on the same plane and weld metal remains within the planes of the surfaces.

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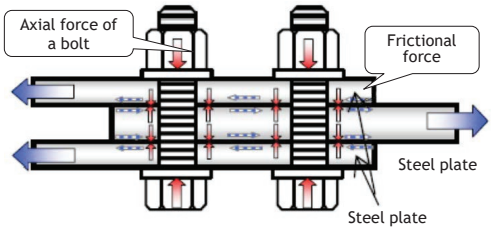
7. Steel structure

4) Connection between steel members cont…

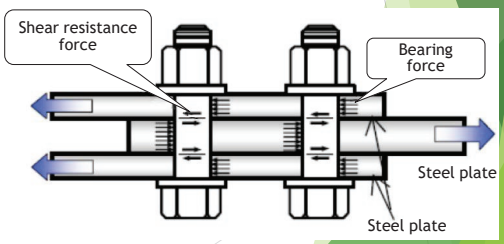
ii. High strength bolted connection

A method of connection between steel plates using high strength bolts.

There are two types of connection methods using high-strength bolts:
1) **Friction grip connection** and, 2) **Bearing connection**.



Friction grip connection



Bearing connection

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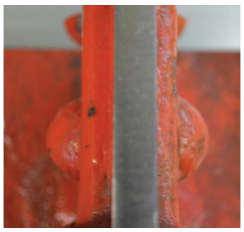
7. Steel structure

4) Connection between steel members cont…

iii. Rivet connection

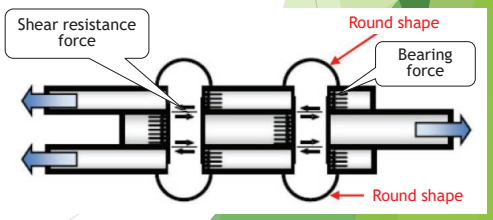
A method of connecting overlapping steel plates by drilling holes and inserting rivets into them.

The principle is the same as that of a bearing connection with high-strength bolt.



Both sides of the shaft are round.

Cut surface of rivet connection



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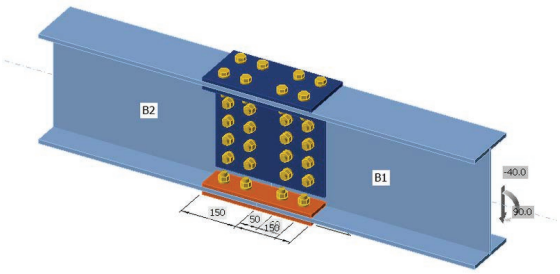
7. Steel structure

4) Connection between steel members cont…

Connection between steel members can be strengthened by adding splice plates, The splice plates can be bolted or welded to the main members. This is to assure continuity for structural members (beams or columns) along their length



Example of a bolted splice joint connection

Tana River Bridge Garissa

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References

- Information on this unit of competence, refer to Inspection Manual for Bridges pages 35-51.

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04-

DEFECTS ON CONCRETE STRUCTURES

1

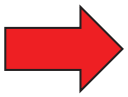
CONTENTS

2

1. Categories of Defects

Categories of Defects

- Initial Defects
- Damages
- Deteriorations
- Obstructions



Common Defects

- Cracks
- Cracks on slab, Slab spalling
- Flaking concrete
- Rebar exposure, Rust
- Water leakage
- Stagnant water
- Free lime (Efflorescence)
- Abnormal expansion gap
- Abnormal sound/Vibration
- Discoloration
- Deformation
- Cross-section loss
- Silt deposits
- Driftwood and plants

The Inspector shall check for these defects at the site and ***propose the possible causes of the defects***.

3

1. Categories of Defects

The defects on concrete structures can be categorized as:

Initial Defects — Anomalies which are caused by design or occur during construction (poor workmanship) e.g., Honeycomb, Cold joint.

Damages — Defect due to external forces e.g., Flood, Vehicular load, Vehicular collision, Earth pressure, Vandalism.

Deteriorations — Defects caused by changes in condition with age e.g., Carbonation, Alkali-silica reaction, Salt damage

Obstructions — Accumulation of debris, driftwoods and stamps, rocks, silt, animals or anything that may impede free flow of water through a structure

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2. Defects and their causes

2.1 Initial Defects

Defects	Causes
(1) Cracks	Drying shrinkage, Heat of hydration of cement, Insufficient compaction, Rapid drying.
(2) Honeycomb	Separation of materials during placing of concrete, Insufficient compaction.
(3) Cold joint	Delay in casting the next section of concrete.
(4) Sand streak	Excessive bleeding water, Formwork gap.
(5) Surface bubble	Casting speed, Insufficient compaction.
(6) Cavity	Dense reinforcement, Insufficient compaction.

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2. Defects and their causes

2.1 Initial Defects cont…

i) Cracks

There are two main reasons why cracks may appear immediately after construction:

i. Internal restraint
ii. External restraint

The above can be attributed to the heat of hydration of the concrete.

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2. Defects and their causes

2.1 Initial Defects cont…

i) Cracks cont…

a. Cracking due to internal restraint

- Concrete generates heat when water reacts with cement. This heat is called **heat of hydration**.
- The heat generated in concrete near the surface drops rapidly through heat dissipation to the atmosphere, however the internal concrete retains the generated heat.
- Concrete near the surface tends to shrink and is constrained by the difference in temperature between the surface and the interior, where the temperature is relatively higher.
- This shrinkage at the surface results in cracking.
- These cracks occur about 1-5 days after placing the concrete.

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2. Defects and their causes

2.1 Initial Defects cont…

i) Cracks cont…

b. Cracking due to external **restraint**

- When the temperature of the freshly cast concrete drops, the existing set concrete does not change in volume, while the newly cast concrete shrinks with the drop in temperature and cracks occur.
- Cracks due to external restraint, unlike internal restraint cracks, appear not only on the surface of the concrete, but often penetrate in the direction of the member's cross-section.
- Cracks due to external restraint occur during the temperature decrease phase, that is, about 1 week after casting the concrete.

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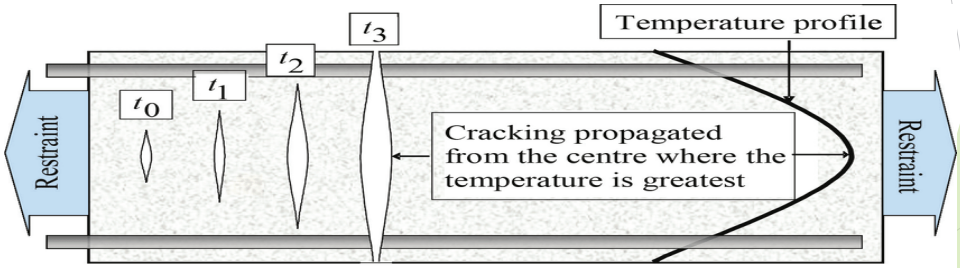
2. Defects and their causes

2.1 Initial Defects cont…

i) Cracks cont…

b. Cracking due to external **restraint**



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2. Defects and their causes

2.1 Initial Defects cont…

ii) Honeycomb

- Honeycomb occurs when concrete has not been adequately compacted.
- The coarse aggregates in concrete is exposed on the surface, giving the appearance of a honeycomb.

It is caused by the separation of mortar and coarse aggregate during the placing of concrete and is formed by the aggregation of coarse aggregate. It is also caused by poor grading of the aggregates.

The honeycomb part is not sufficiently strong because the mortar is not well spread, and it is also not dense, so air and moisture can easily enter, leading to corrosion of the steel bars.

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2. Defects and their causes

2.1 Initial Defects cont…

iii) Cold joint

- A cold joint is formed when the first layer of concrete sets before the next layer is cast.
- Unlike normal construction joints, the joints are not treated, which means that the joints are the weak points in the concrete.
- Deterioration of the structure can easily start at this point.

Cold Joint on abutment

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2. Defects and their causes

2.1 Initial Defects cont…

iv) Sand streak

- This occurs when there is a large amount of water in the concrete and the water move upwards along the formwork through material separation.
- In the bottom photo, this is caused by the cement paste leaking out of the formwork through the joints and gaps.
- This is not an aesthetic finish. The concrete surface is less strong and more susceptible to wear.

Sand streak

Sand streak

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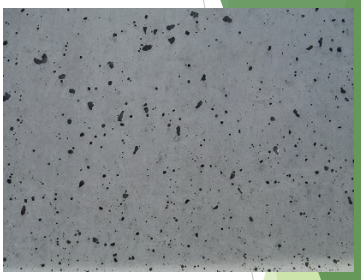
2. Defects and their causes

2.1 Initial Defects cont…

v) Surface bubble

- Air bubbles that are trapped in the concrete and appear on the surface.



This is not an aesthetic finish, and the concrete surface is thus weaker and more susceptible to damage.

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2. Defects and their causes

2.1 Initial Defects cont…

vi) Cavity

- Unfilled areas in the concrete due to congested (narrowly spaced) reinforcement, uneven or complex formwork shape or insufficient compaction of the concrete.
- Inadequate grouting in the sheath of prestressed concrete structures may result in cavities.

Cavity under the rebar

The cause of this defect is the same as for Honeycomb.

As shown in the picture, this defect allows ingress of water leading to corrosion of steel bars and water leakage.

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2. Defects and their causes

2.2 Damages

Defect due to external forces e.g., Flood, Vehicular load, Vehicular collision, Earth pressure, Vandalism.

i) Vehicle Collision
Impact by vehicles exceeding the allowable height limit

ii) Earth Pressure
Rotation of the wing wall due to pressure from the backfill.

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2. Defects and their causes

2.3 Deteriorations

The changes in condition with age, e.g. Carbonation, Salt Attack, Alkali-silica reaction, chemical attack, fatigue, etc.

Deteriorations	Major deterioration factors
i) Carbonation	Carbon dioxide
ii) Salt Attack	Chloride ions
iii) Alkali-silica reaction	Reactive aggregate, Alkaline components, Moisture
iv) Chemical Attack	Acids, Sulfate ions
v) Fatigue	Repeated load, Heavy vehicle traffic volume

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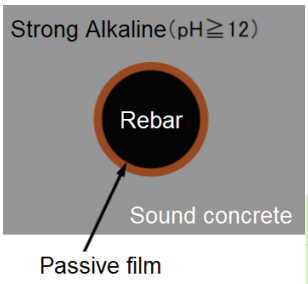
2. Defects and their causes

2.3 Deteriorations cont…

Fundamental Knowledge of Concrete

Sound concrete conditions

- $Ca(OH)_2$ is present in large amounts in the concrete, maintain a strong alkaline of pH 12 or higher.
- Thus, the rebar does not rust since it is protected by a passive film.



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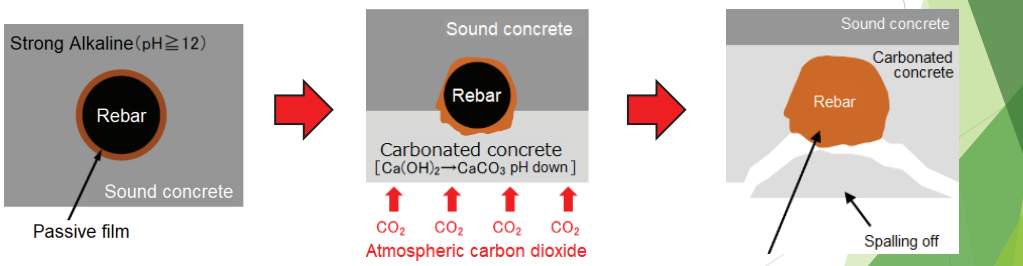
2. Defects and their causes

2.3 Deteriorations cont…

i) Carbonation

$Ca(OH)_2$ in the concrete reacts with CO_2, to form $CaCO_3$, and the pH decreases therefore destroying the passive film. The rebar will rust causing cracks in concrete due to the expansion pressure from the corroded rebar.



Atmospheric carbon dioxide permeates into the concrete.

When steel rusts, it becomes 2-3 times larger than its original volume.

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2. Defects and their causes

2.3 Deteriorations cont…

i) Carbonation cont…

- The above photos show corroded rebars due to carbonation of concrete leading to spalling of concrete cover.
- The thickness of the concrete cover should be inspected during construction to ensure that it is as designed.

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2. Defects and their causes

2.3 Deteriorations cont…

i) Carbonation cont…

Examples of areas where this is likely to occur.

- Carbonation of concrete is caused by carbon dioxide in the atmosphere and therefore can occur anywhere.

Countermeasures

- For concrete structures that have already been constructed, a surface coating can be applied to inhibit carbon dioxide ingress.
- Place concrete and compact adequately during construction providing adequate cover.

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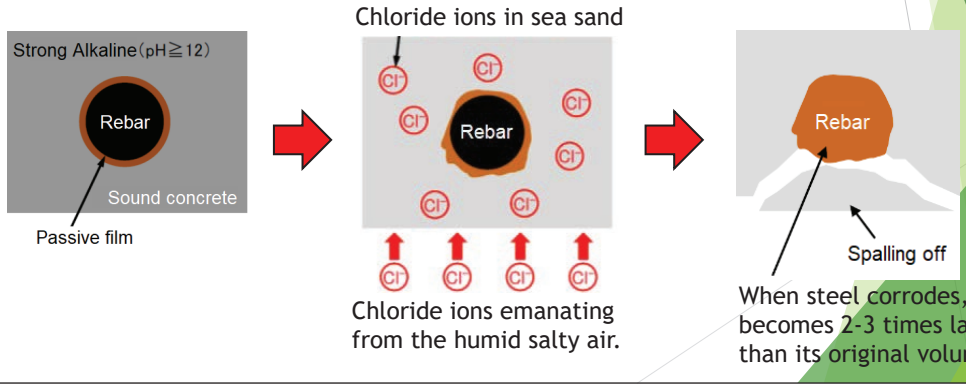
2. Defects and their causes

2.3 Deteriorations cont…

ii) Salt Attack/Chloride Induced Deterioration

The chloride ions destroy the passive film making the steel bars in the concrete to rust. The expansion pressure of the corroded rebar causes cracks to appear.



2. Defects and their causes

2.3 Deteriorations cont…

ii) Salt Attack cont…

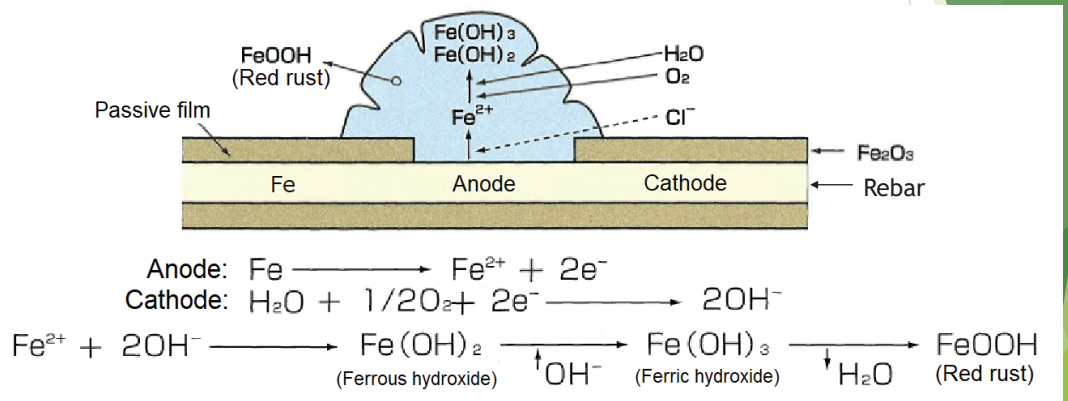


Figure. Mechanism of Salt Attack

2. Defects and their causes

2.3 Deteriorations cont…

ii) Salt Attack cont…

- The rebar is corroded by the salt emanating from the humid salty air causing spalling of the concrete cover.

NOTE

If you see cracks along the rebar direction in the coastal area, suspect salt Attack!

Nyali Bridge Abutment

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2. Defects and their causes

2.3 Deteriorations cont…

ii) Salt Attack cont…

Comparison between Salt Attack and Carbonation

- Salt attack is caused by chloride ions, while carbonation is caused by carbon dioxide.
- Both salt attack and carbonation are the same in that the reinforcing bar corrodes and the concrete cover spalls off.

NOTE: It is necessary to clarify which of the two is the cause of the deterioration, because different factors of deterioration require different countermeasures.

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2. Defects and their causes

2.3 Deteriorations cont…

iii) Alkali-Silica Reaction

- When aggregates in concrete contain alkali-reactive minerals such as opal, cristobalite, and tridymite, they react with the alkaline components in the concrete to generate alkali-silica gel. The alkali-silica gel is a substances that expands when it absorbs water.
- This reaction is called "Alkali Silica Reaction (ASR)".
- As the gel absorbs water and expands, cracks appear in the concrete.

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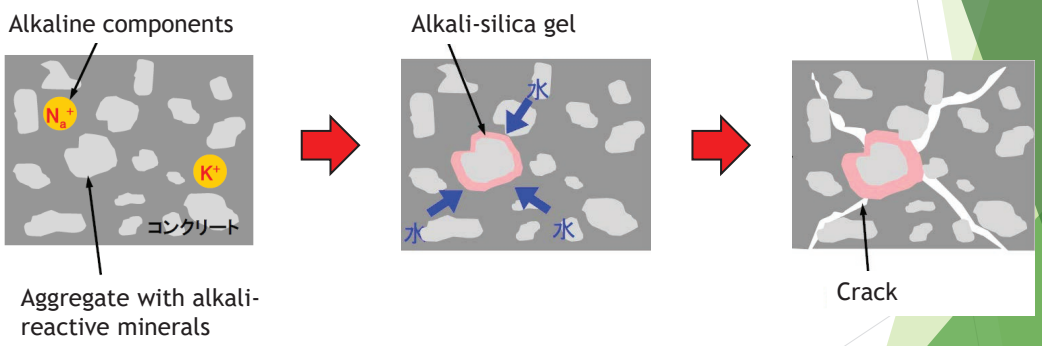
2. Defects and their causes

2.3 Deteriorations cont…

iii) Alkali-Silica Reaction cont…



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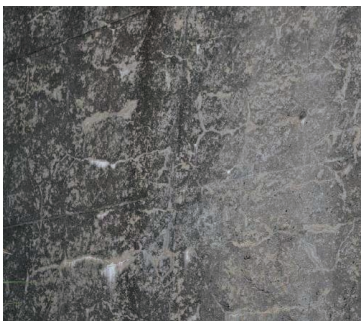
2. Defects and their causes

2.3 Deteriorations cont…

iii) Alkali-Silica Reaction cont…


- Cracks caused by alkali-silica reaction will form aligator cracks, as shown in the photos above.

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2. Defects and their causes

2.3 Deteriorations cont…

iv) Chemical Attack

- When concrete structures are exposed to reactive liquids and gases, acidic and saline environment, effluent from sewage facilities and sulphates chemical corrosion occurs.
- Such structures may be found in;
  - Industrial factories that use/discharge acids and various salts
  - Sewerage facility
  - Offshore structures
  - Structures in the soil containing sulphates etc.

Concrete foundation that was in soil containing sulphates

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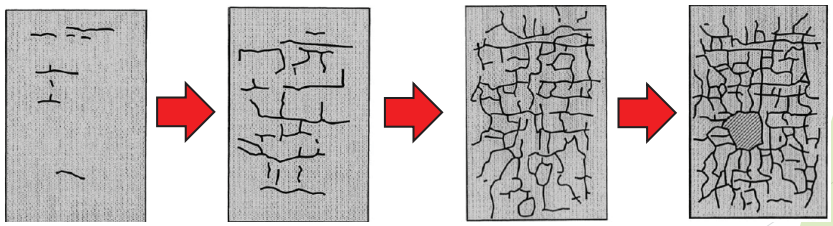
2. Defects and their causes

2.3 Deteriorations cont…

v) Fatigue

Deck slab is most frequently damaged by fatigue because it directly support the repeated loads by heavy vehicles.

Progress of deterioration by fatigue in RC Slabs of Road Bridges



Stage	I	II	III	IV
	Cracks in one direction	Cracks in two directions	Reticulation of cracks	Falling out of concrete slab

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2. Defects and their causes

2.3 Deteriorations cont…

v) Fatigue cont…

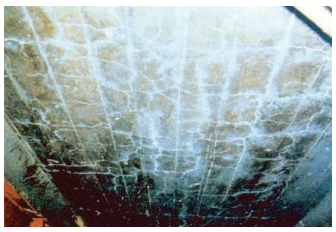

Photo in stage II

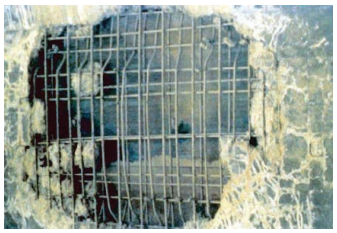

Photo in stage IV

- From the viewpoint of preventive maintenance, it is desirable to conduct repair work using the crack injection method, waterproofing, sectional repair etc. at Stage II, because large-scale repair work with traffic control will be required at Stage IV.

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2. Defects and their causes

2.4 Obstructions

Driftwoods

- This is the accumulation of unwanted material on the structures, the unwanted materials interfere with the free flow of water through the structures.

Photo showing driftwood blocking a box culvert

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References

Information on this unit of competence, refer to Inspection Manual for Bridges pages 60-78.

05-
DEFECTS ON
STEEL STRUCTURE

1

CONTENTS

2

1. Categories of Defects

Categories of Defects

- Initial Defects
- Damages
- Deteriorations
- Obstructions

The Inspector shall check for these defects at the site and ***propose the possible causes of the defects***.

Types of Defects

- Corrosion
- Cracks
- Fracture/Buckling/Deformation
- Loose and missing bolts
- Deterioration of corrosion protection
- Damage to reinforcing members
- Abnormalities in expansion gap
- Abnormalities in joints
- Water leakage/stagnation
- Abnormal sound/Vibration
- Abnormal deflection
- Silt deposits
- Driftwood and plants

3

1. Categories of Defects

Types of Defects

- Corrosion
- Cracks
- Fracture/Buckling/Deformation
- Loose and missing bolts
- Deterioration of corrosion protection
- Damage to reinforcing members
- Abnormalities in expansion gap
- Abnormalities in joints
- Water leakage/stagnation
- Abnormal sound/Vibration
- Abnormal deflection
- Silt deposits
- Driftwood and plants

- *Effects on third parties*
  Falling of parts, Noise and Vibration
- *Effects on road users:*
  Falling of parts, Abnormality in expansion gap
- *Degradation of the safety of the structure*
  Corrosion, Cracks, Fracture, Buckling, Abnormal deflection etc.

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1. Categories of Defects

Defects on steel structures can be categorized as:

Initial Defects	Anomalies which are caused by design or occur during construction (poor workmanship) e.g., Welding defects, Insufficient paint thickness, Insufficient bolt tightening torque, Poor fabrication etc.
Damages	Defects due to external forces e.g., flood, vehicle load, vehicle collision, vandalism, etc. The damages may include deformation, missing bolts/steel members etc.,
Deteriorations	Defects caused by changes in condition with age e.g., corrosion, deterioration of corrosion protection, abnormal deflection, cracks, fracture etc.
Obstructions	Accumulation of debris, driftwoods and stamps, rocks, silt, animals or anything that may impede free flow of water through a structure

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2. Causes of Defects

2.1 Initial Defects

- The probability of initial defects in steel bridges is lower than that in concrete bridges.
- However, inspection during fabrication and construction is essential because there is a possibility that defects such as welding defects and insufficient paint thickness may occur.

A steel bridge can be used for more than 100 years if properly maintained.

George Adamson Bridge in Meru National park Kenya.

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2. Defects and their causes

2.1 Initial Defects cont…

The quality of steel structures is consistent unlike concrete structures.

As shown in the photos above, the manufacturing of steel plates (left) and their processing and fabrication into bridge members (right) are carried out under strict quality control in the factory.

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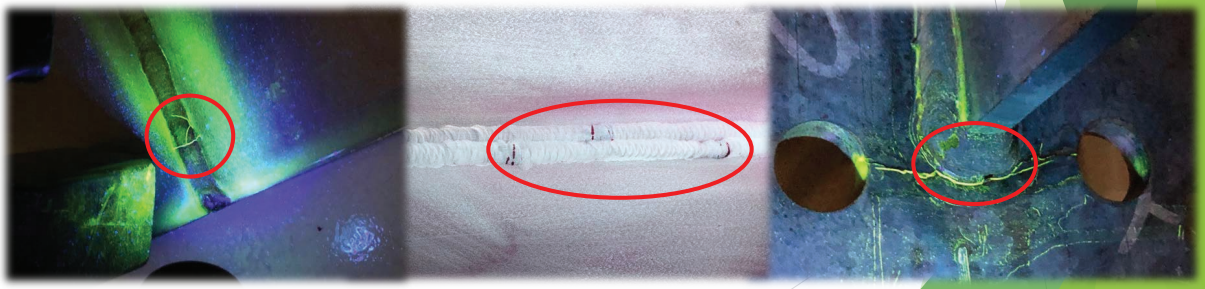
2. Defects and their causes

2.1 Initial Defects cont…

Welding defects

The metal made by welding is called “bead”.

Various defects are likely to occur around the bead as shown in the photos below:



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2. Defects and their causes

2.2 Damages

i) Vandalism and accidents

- Missing steel members of the guardrails and/or superstructure due to vandalism or accidents.





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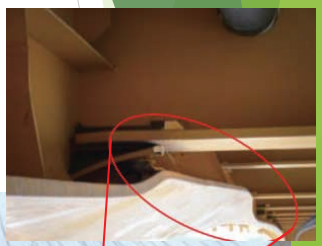
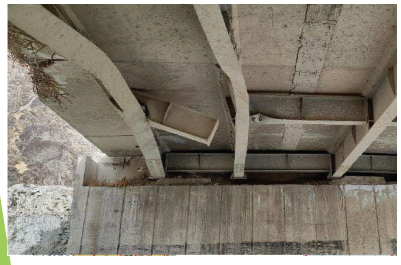
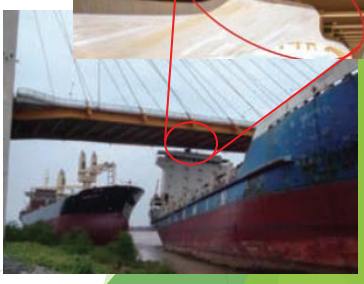
2. Defects and their causes

2.2 Damages cont…

ii) Collision

- The photo on the left shows damage caused by rock collision during a flood.
- The photos at the center and right show damages caused by vehicle and ship collision respectively.

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2. Defects and their causes

2.3 Deteriorations

Changes in condition with age e.g. Corrosion, Deterioration of corrosion protection, Cracks and fractures, Loose and missing bolts, Abnormal deflection, etc.

Defects	Major deterioration factor
i) Deterioration of corrosion protection	Water, Ultraviolet, Chloride ions
ii) Corrosion	Water, Air(Oxygen)
iii) Cracks and fractures	Fatigue, External forces
iv) Loose and missing bolts	Vibration caused by passing vehicles
v) Damage at the girder end	Acids, Sulfate ions
vi) Abnormal deflection	Overloading, Fatigue

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2. Defects and their causes

2.3 Deteriorations

i) Deterioration of corrosion protection

- Deterioration of corrosion protection is defined as the occurrence of minor rusting without thickness reduction or sectional loss.

Deterioration of corrosion protection

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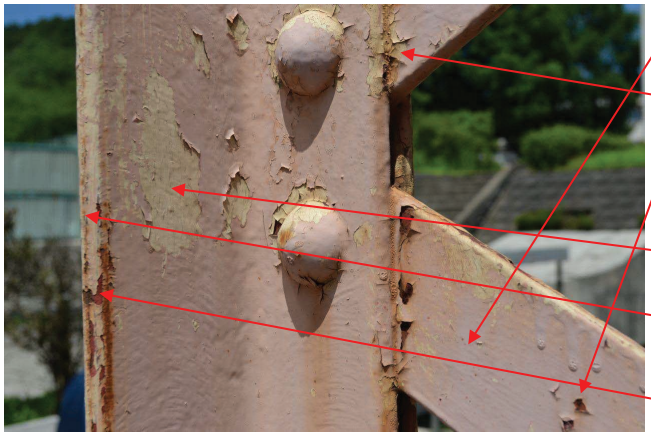
2. Causes of Defects

2.3 Deteriorations cont…

i) Deterioration of corrosion protection cont…



1. Chalking
2. Pin hole
3. Crack
4. Peeling of paint
   - Topcoat
   - Middle-coat, Undercoat
5. Rust, Corrosion

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2. Causes of Defects

2.3 Deteriorations cont…

i) Deterioration of corrosion protection cont…

Deterioration of paint on members

Paint film is deteriorated leading to corrosion . Deterioration will be accelerated due to the loss of corrosion protection

Weak adhesion between coats due to poor paint quality/ lack primer.

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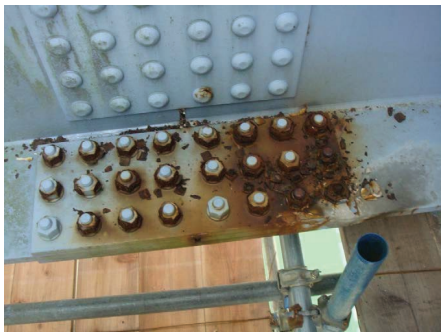
2. Causes of Defects

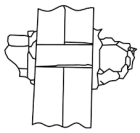
2.3 Deteriorations cont…

i) Deterioration of corrosion protection cont…

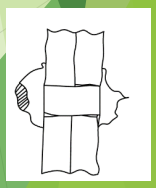
Deterioration of Paint on Bolts



As the deterioration progresses, the steel and bolts corrode.



High Strength Bolt



Rivet

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2. Defects and their causes

2.3 Deteriorations cont…

ii) Corrosion

- Corrosion is defined as intensive rusting, or rusting that has progressed to such an extent that thickness reduction or cross-sectional loss has occurred.

Corrosion of bottom flange

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2. Defects and their causes

2.3 Deteriorations cont…

ii) Corrosion cont…

Causes of deteriorations	Impact on structures
➢ Water leakage from cracks on the deck slab ➢ Inadequate waterproofing layer on deck slab ➢ Water leakage from drainage facilities and expansion joints ➢ Natural environment (adhered salt) ➢ Sediment clogging ➢ Stagnant water	➢ Excess stress due to section loss ➢ Cracking due to stress concentration ➢ Reduction of girder stiffness and load carrying capacity due to corrosion at the joint between main girder and deck slab

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2. Defects and their causes

2.3 Deteriorations cont…

ii) Corrosion cont…

Corrosion Mechanism

- Corrosion occurs in a mixture of iron, oxygen and water/moisture, and is accelerated in an environment where corrosive substances (such as atmospheric sulfurous gases and sea salt particles) are mixed with water/moisture.
- However, if there is no water/moisture, corrosion will not be accelerated.
- Therefore, maintenance of drainage facilities is very important.

Moisture elimination is the best way to prevent damage due to corrosion.

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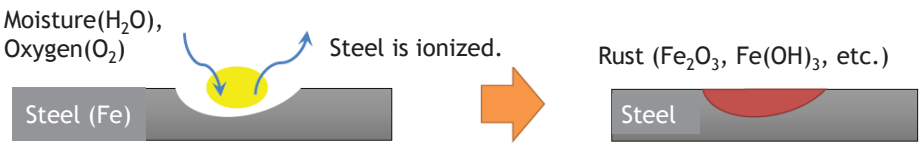
2. Defects and their causes

2.3 Deteriorations cont…

ii) Corrosion cont…

Corrosion Mechanism



Point!

- Rust is a compound of a reaction between iron, water and oxygen.
- Rust is the most stable state of iron ore.
- In general, metals try to return to a stable state.

2. Defects and their causes

2.3 Deteriorations cont…

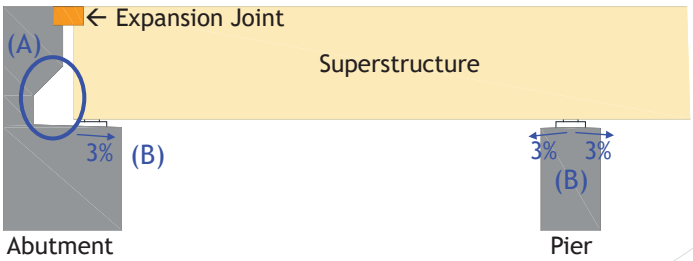
ii) Corrosion cont…

What are the necessary steps one should take to eliminate moisture?

(a) Allow for adequate space around the bearing to prevent moisture accumulation.
(b) Provide a slope on the bearing seat for drainage.

} Consider in design stage

(c) Cleaning of the bearing seat → In maintenance stage



2. Defects and their causes

2.3 Deteriorations cont…

ii) Corrosion cont…

The following locations are susceptible to corrosion and deterioration of corrosion protection performance.

- Girder ends with frequent water leakage
- Around drainage facilities
- Top surface of horizontal members and bottom flange where mud and dust accumulate
- Around the bearings
- Splicing parts with poor ventilation and drainage
- Welded area
- High strength bolts, etc.

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2. Defects and their causes

2.3 Deteriorations cont…

ii) Corrosion cont…

	
Girder ends with frequent water leakage	Around drainage facilities

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2. Defects and their causes

2.3 Deteriorations cont…

ii) Corrosion cont…

Top surface of horizontal members and bottom flange

Around the bearings

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2. Defects and their causes

2.3 Deteriorations cont…

ii) Corrosion cont…

Welded area

High Strength Bolts

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2. Defects and their causes

2.3 Deteriorations cont…

ii) Corrosion cont…

Corrosion on Girders

- The girder end is susceptible to corrosion due to water leakage from the expansion joint, water stagnation and sedimentation.
- The top surface of the lower flange is also susceptible to corrosion because water tends to accumulate on it.



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2. Defects and their causes

2.3 Deteriorations cont…

ii) Corrosion cont…

Embedded part in concrete

- The part embedded in the concrete is prone to corrosion because of water seepage into the gap between the concrete and steel.
- This action is not visible and might go on unnoticed.



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2. Defects and their causes

2.3 Deteriorations cont…

iii) Cracks and fractures

- Cracks often appear at points where the cross-section of a member suddenly changes or at welded joints, where stress concentration is likely to occur including connections on the secondary members.
- Fatigue cracking is susceptible in areas where paint film has cracked and rusty fluids are observed.
- Fractures often appear on secondary members such as floor frame members, cross frame and lateral bracings, bridge railings and their attachments.

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2. Defects and their causes

2.3 Deteriorations cont…

iii) Cracks and fractures cont…

Fatigue

- Fatigue is a phenomenon in which cracks develop on steel members and propagate under the influence of repeated stresses.
- Fatigue on steel members tends to occur at stress concentration points, often at welded parts.

Repeated stress →

- Areas of structural stress concentration
- Locations where stress concentrates due to weld shape, weld defects, etc.

→ Fatigue cracks

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2. Defects and their causes

2.3 Deteriorations cont…

iii) Cracks and fractures cont…

Cracks on Painting

Points to consider when diagnosing cracks on paints

- There is a possibility of existence of a larger crack on steel hidden under the visible paint crack.
- In order to accurately determine the presence and extent of cracks, it is necessary to conduct Magnetic-particle Testing (MT) with the painting removed.

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2. Defects and their causes

2.3 Deteriorations cont…

iii) Cracks and fractures cont…

Repaired and Reinforced areas

A repaired and/or reinforced area is an area that has been damaged before.

Points to consider when diagnosing cracks in repaired and reinforced areas

- Except when the structural system is changed by large-scale retrofit work, even if after repair and/or reinforcement, the structural system of the whole structure will be unchanged, and it is still a place where stress is concentrated.
- Carefully inspect the repaired or reinforced area for fatigue cracks that have occurred in the past, as there is a possibility of cracks to progress.
- There is a possibility of similar cracks and damage in the same areas where the structural details are the same as in the past.

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2. Defects and their causes

2.3 Obstructions

Silt deposits and driftwoods

- This is the accumulation of unwanted material on the structures, the unwanted materials interfere with the free flow of water through the structures.

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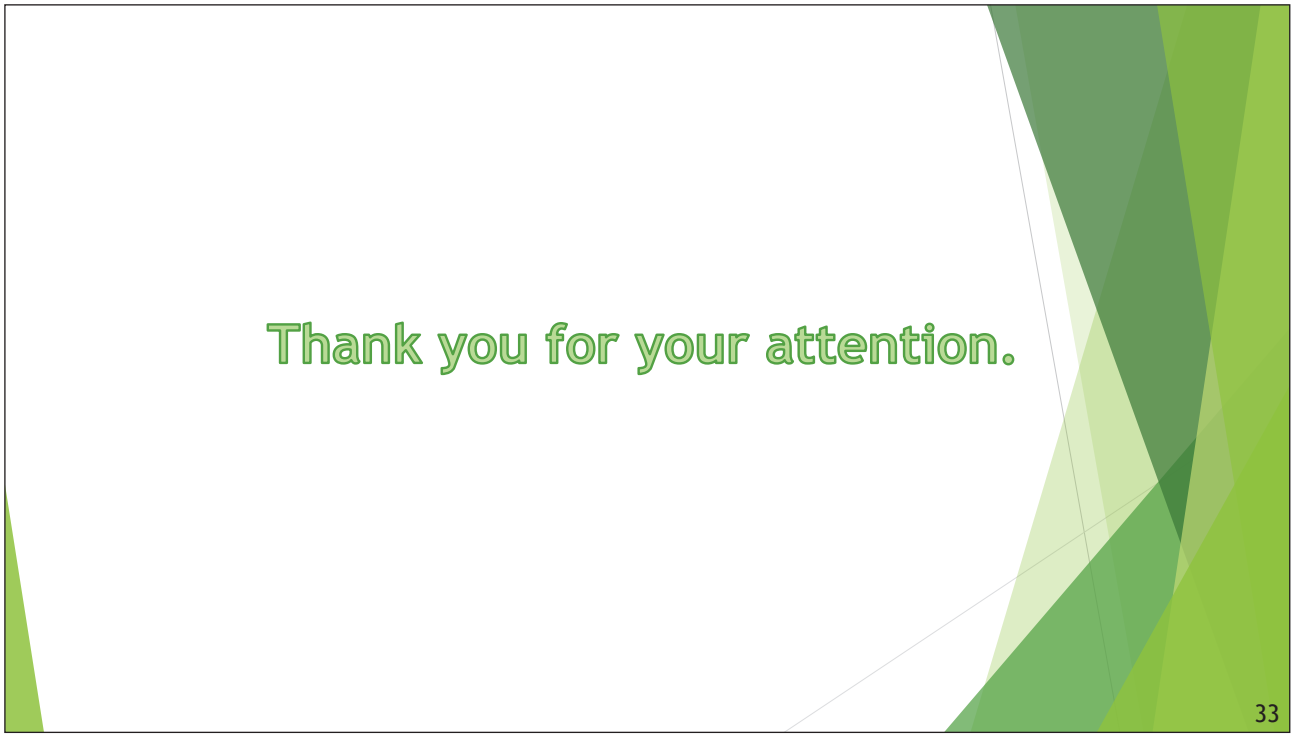
References

Information on this unit of competence, refer to Inspection Manual for Bridges pages 78-89.


Thank you for your attention.
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06-
DAMAGE EXAMPLES ON CONCRETE STRUCTURES

1

CONTENTS

1. Purpose of this module
2. Definition of Defect Level
3. Defects on Concrete Structures

2

Purpose of this module

- The purpose of this module is to train bridge inspectors and engineers to have the skills to determine the extent of defects found at the inspection site.
- There are four defect levels discussed in this module, however, they are not absolute.
- In particular, Defect Level I (DL I) or Defect Level II (DL II) often varies from inspector to inspector, but it is important to be able to explain the reason for his/ her judgement.

3

1. Definition of Defect Level

Defect Level	Notation	Description
N	Minor defects	Defects that require no action
DL I	Defect to observe or do minor maintenance	Defects do not compromise the structural integrity of the structure.
DL II	Defects need action (Not urgent)	Defects that may compromise the structural integrity if action is not taken in the short term.
DL III	Serious defects (Need urgent action)	Defect that has significantly compromised the structural integrity of the structure/high risk.

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2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Damage/ Deterioration	• Vehicle collision • Rebar corrosion
	Defect Name	**Countermeasures**
	Spalling exposing rebars	• Section repair/Patching with non shrinkage mortar/ cement paste after cleaning on the surface of concrete and rebar.
Description		**Defect Level**
Concrete on the main girder is peeling off. The rebars are exposed and corroded.		DL II

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2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Deterioration	• Rebar expansion caused by corrosion
	Defect Name	**Countermeasures**
	Spalling exposing rebars	• Section repair by non shrinkage mortar/cement paste after cleaning on the surface of concrete and rebar.
Description		**Defect Level**
Concrete is peeling off. The rebar is exposed and corroded.		DL II

6

2. Defects on Concrete Structures

Defect Photo	Defect Category	Possible causes
	Damage	• Flood scouring
	Defect Name	**Countermeasures**
	Abrasion/ Erosion	• Protection of the bank by gabion mattress/Riprap • Repair the concrete retaining wall
Description		**Defect Level**
Erosion of embankment. Destroyed concrete retaining wall.		DL I

7

2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Initial Defect	• Poor workmanship • Abrasion by flooding • Frost damage
	Defect Name	**Countermeasures**
	Honeycomb/ Exposed rebars	• Reconstruction
Description		**Defect Level**
Concrete is peeling off and the rebars are exposed and thinning. Honeycomb on the front side of concrete wall.		DL III

8

2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Deterioration	• Water infiltration from the top
	Defect Name	**Countermeasures**
	Efflorescence	• Unclog the drains • Waterproofing to stop infiltration
Description		**Defect Level**
Free lime is observed from the gap between the girders. Sectional loss is not observed.		DL I

9

2. Defects on Concrete Structures

Defect Photo	Defect Category	Possible Causes
	Damage	• Collision of flowing objects during flood • Abrasion by flood water
	Defect Name	**Countermeasures**
	Abrasion	• Reconstruction
Description		**Defect Level**
Concrete substructure is destroyed.		DL III

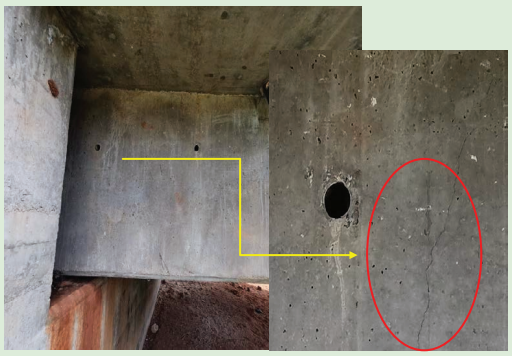
10

2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Damage	• Erosion of the riverbed as a result of flowing water
	Defect Name	**Countermeasures**
	Sapping/ Scouring	• Provide water calming features on the outlet i.e. rip rap and gabion works
Description		**Defect Level**
Erosion on the box culvert outlet exposing the foundation		DL II

11

2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Damage	• Distress due to loading
	Defect Name	**Countermeasures**
	Crack	• Crack sealing / • Strengthen the member
Description		**Defect Level**
Crack on the girder end		II

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2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Obstruction	• Accumulated silt.
	Defect name	**Countermeasures**
	Siltation	• Remove the silt deposits
Description		**Defect Level**
Box culvert cell half filled with silt deposits		DL II

13

2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Damage	• Corrosion of rebars • Impact/ Hit by road users
	Defect name	**Countermeasures**
	Spalling exposing rebars	• Sectional repair
Description		**Defect Level**
Kerbs rebars exposed		DL I

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2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Damage	• Scouring due to eroding action of river flow
	Defect name	**Countermeasures**
	Scouring	• Provide adequate protection works
Description		**Defect Level**
Exposed piles		DL II

15

2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Initial defect	• Inadequate execution/ poor workmanship
	Defect name	**Countermeasures**
	Unfilled sampling hole	• Fill the hole with suitable material
Description		**Defect Level**
Hole in a wrong location, middle of the deck.		DL I

16

2. Defects on Concrete Structures

Defect Photo	Defect Category	Possible causes
	Deterioration	• Overloading • Fatigue
	Defect name	**Countermeasures**
	Crack	• Waterproofing slab on top and crack sealing the bottom • Strengthening with carbon-fibre sheet.
Description		**Defect Level**
Cracks developing on the bottom of the slab		DL II

17

2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Damage	• Cracks developing due to load transmitted to the abutment wall
	Defect name	**Countermeasures**
	Cracks	• Seal the cracks using and epoxy material
Description		**Defect Level**
Cracks developed on the abutment, small concrete section almost falling off.		DL I

18

2. Defects on Concrete Structures

Defects Photo	Defect category	Possible causes
	Damage/Obstruction	• Leaking expansion joints lead to silt deposits on the bearing seat of the bridge which encourages vegetation growth.
	Defect name	**Countermeasures**
	• Vegetation growth/ Siltation • Exposed rebars	• Clean the expansion joints and waterproof with epoxy material.
Description		**Defect Level**
Vegetation growth on the bearing seat area of the pier. Exposed rebars on the pier wall.		DL I

19

2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Obstruction/ Deterioration	• Inadequate vegetation control measures • Inadequate cover
	Defect name	**Countermeasures**
	Vegetation growth Exposed rebars	• Cut the overgrown vegetation to manageable levels • Section repair by patching
Description		**Defect Level**
Overgrown vegetation around the structure and exposed rebars on the girders.		DL I

20

2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Damage	• Scouring at the culvert mouth due to volume and speed of flow • Inadequate design and execution
	Defect name	**Countermeasures**
	Scouring Wingwall failure	• Repair and protect the embankment with gabions • Provide a reliever structure.
Description		**Defect Level**
Part of the road structure has collapsed due to the scouring at the culvert mouth		DL III

21

2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Initial defect/ deterioration.	• Under design • Overloading • Fatigue
	Defect name	**Countermeasures**
	Excessive deflection of the girders. Delamination of the wingwall.	• Strengthening the girders.
Description		**Defect Level**
Visible deflection of girders, critical distance from the support and delaminated wingwall.		DL I

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2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Initial defect	• Settlement of the fill material behind the abutments due to self compaction / wheel load • Missing approach slab
	Defect name	**Countermeasures**
	Settlement	• Fill the area with suitable backfill material and compact adequately • Provide approach slab on both approaches
Description		**Defect Level**
Settlement of the approach		DL II

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2. Defects on Concrete Structures

Defect Photo	Defect category	Possible causes
	Deterioration	• Poor workmanship • Low quality concrete • Water infiltration • Inadequate cover
	Defect name	**Countermeasures**
	Spalling exposing rebars	• Reconstruction
Description		**Defect Level**
Concrete is peeling off. Rebars are exposed and the stirrup bars are thinning/lost.		DL III

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References

Information on slide 4, refer to Inspection Manual for Bridges pages 60-78.

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07-
KEY POINTS OF
BRIDGE INSPECTION

1

CONTENTS

2

1. Roles of Bridge Administrator

Bridge administrator shall ensure that the following are fulfilled:

- Safe and smooth flow of traffic
- Durability and enforcing design load limit of a structure
- Prevention of occurrence of uncertainties to third parties

What should be done to prevent road accidents and bridge collapses?

- Early detection of hazards that may hinder traffic
- Early detection of abnormalities and damages on the bridges

then

Take appropriate countermeasures
(Repair and Reinforcement etc.)

3

1. Roles of Bridge Administrator

Bridge Management System (BMS)

- Bridge administrator charged with the mandate to maintain Kenyan Road networks, shall be responsible for inputting the inspection result data for roads under their jurisdiction, in the BMS Database using inspection application.
- Bridge Management System is an online database for storage and management of bridge data to facilitate design, construction, operation, maintenance, monitoring and resource planning for structures.
- The database function of storing all collected data from an inspection will support the bridge asset management. The damage score of the bridge is automatically calculated and thus inform maintenance option.

4

1. Roles of Bridge Administrator

The bridge administrator should be able to conduct different types of inspections to enable early detection of bridge anomalies.

Types of Bridge Inspection

Types of Inspection	Objective and description of inspection
Baseline Inspection	An initial inspection conducted once on a new bridge or an existing bridge to determine the primary condition.
Routine inspection for PBC	Inspection to confirm the serviceability of a bridge conducted at least once a month to check for defects with an aim of ensuring smooth traffic flow and preventing damage/hazards to third parties.
Routine inspection for ARBICS	This inspection is carried out annually to obtain bridge condition information for maintenance planning purposes.

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1. Roles of Bridge Administrator

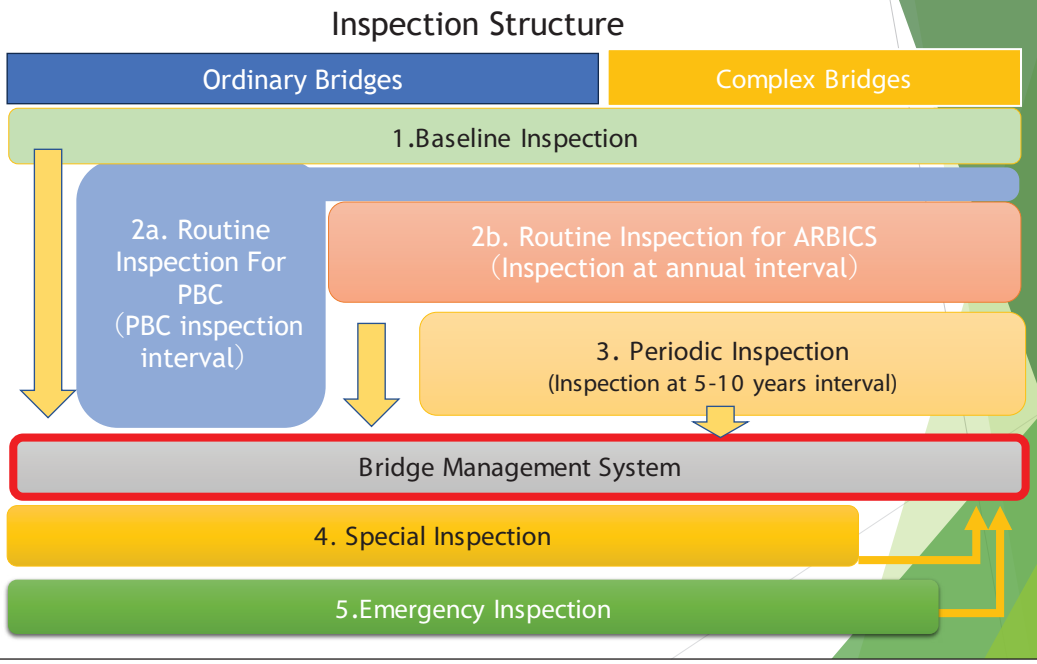
Periodic inspections enable early detection of bridge anomalies.

Types of Bridge Inspection cont…

Types of Inspection	Objective and description of inspection
Periodic inspection	The inspection is for checking the soundness of the structure and shall be conducted at intervals of 5 years.
Special Inspection	The inspection is conducted for diagnostic study to examine the cause and extent of damage based on the findings from previous inspections.
Emergency Inspection	Emergency inspection is carried out after detection of severe defects and abnormalities on a bridge after a natural disaster or accident.

6

1. Roles of Bridge Administrator



7

2. Bridge Inspection Procedure

Park in a safe place.

Check that the inspection equipment is working properly.
Safety checks (helmets, reflectors, safety belts, etc.)

Visually inspect the whole bridge to check whether there are any deformities without using the inspection application.

Inspect in detail for existence of cracks, spalling concrete, rebar exposure etc. Then record the data in the BMS.

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3. Key Points of Bridge Inspection

First, Visually CHECK the whole bridge before using the bridge inspection application on smartphone, then INSPECT in detail.

Note: Do not carryout detailed inspection from the beginning.

- Since a bridge does not collapse without warning, obvious and visible abnormalities appear before it collapses.
- Therefore, the first step is to check the whole bridge for any abnormalities (uneven road profile, deflection of the main girders, inclination of the abutments or piers, etc.)

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3. Key Points for Bridge Inspection

3.1 Check points for inspection of the whole bridge

1. Road condition
   - Existence of unevenness on the pavement
   - Existence of potholes on the pavement
   - Abnormalities at the expansion joints
2. Condition of the superstructure
   - Deflection of the main girders
   - Misalignment of the railing profile
3. Condition of the substructure
   - Settlement or inclination of abutments/piers

*1 should be inspected from the road
*2 and 3 should be inspected from side and under the bridge respectively

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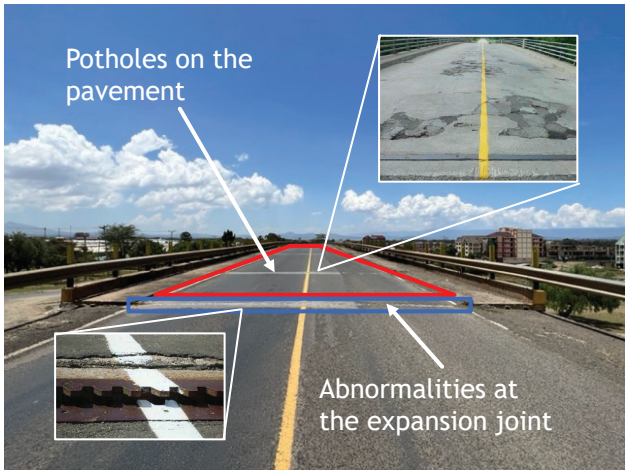
3. Key Points for Bridge Inspection

3.1 Check points for inspection of the whole bridge cont…

1. General inspection of the road condition



First, check for major damages that may pose structural and traffic safety challenges.

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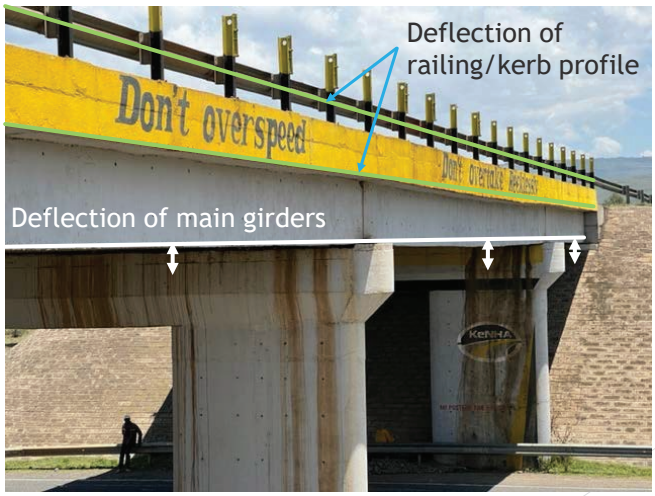
3. Key Points for Bridge Inspection

3.1 Check points for inspection of the whole bridge cont…

2. Inspection of the superstructure



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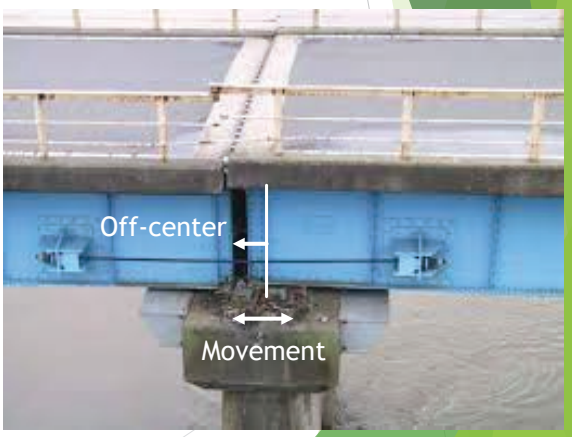
3. Key Points for Bridge Inspection

3.1 Check points for inspection of the whole bridge cont…

3. Inspection of the substructure



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3. Key Points for Bridge Inspection

3.2 Check points for detailed inspection

1. Road condition
   - Damages on railings, protective fences and kerbs
   - Clogging of the drainage systems.
   - Cracks on the pavement
2. Condition of the superstructure
   - Cracks on the main girders/deck slab
   - Spalling of concrete girders/deck slab etc.
3. Condition of the substructure
   - Cracks on the abutments/piers
   - Scouring around the abutments/piers
   - Siltation on bearing seats, lower slabs etc.

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3. Key Points for Bridge Inspection

3.2 Check points for detailed inspection cont…

Detailed road inspection

Damages on railings, guardrails, fences, and kerbs

Clogging of the drainage facilities

Crack on pavement

- Record the observed defects in the bridge management system using the inspection application

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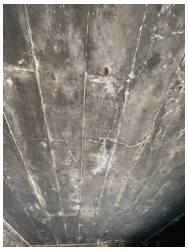
3. Key Points for Bridge Inspection

3.2 Check points for detailed inspection cont…

Detailed inspection of the superstructure

Rebar fractures and cracks on the main girder/cross beam

Free lime



Cracks on the deck slab

Vandalization of the lighting facility

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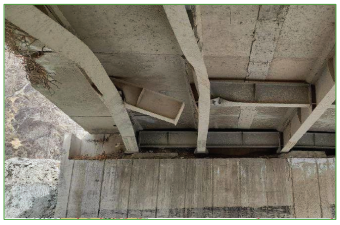
3. Key Points for Bridge Inspection

3.2 Check points for detailed inspection cont…

Detailed inspection of the superstructure




Deformation of steel girder/bracing


Corrosion of steel girder

Corrosion of bearings


Missing and Corrosion of Bolts

Cracks on steel member

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3. Key Points for Bridge Inspection

3.2 Check points for detailed inspection cont…

Detailed inspection of the substructure


Siltation/Sedimentation on the bridge seat


Cracks on the abutment/Retaining wall


Sectional loss and Rebar exposure of pier concrete

Scouring

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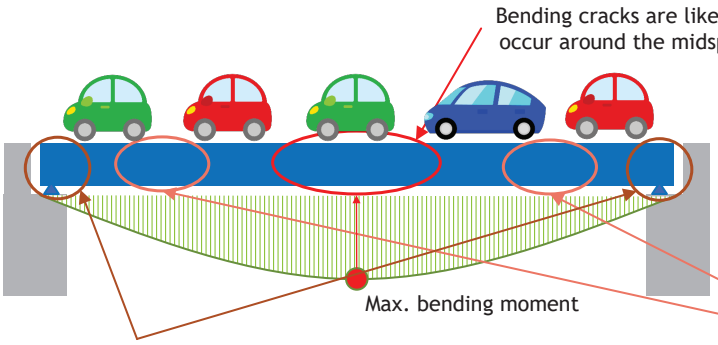
3. Key Points for Bridge Inspection

3.3 Areas to be inspected

(1) Simply supported bridge



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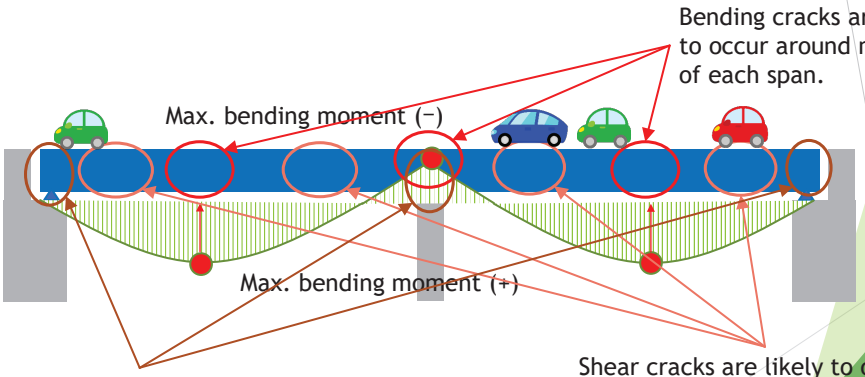
3. Key Points for Bridge Inspection

3.3 Areas to be inspected cont…

(2) Continuously supported bridge



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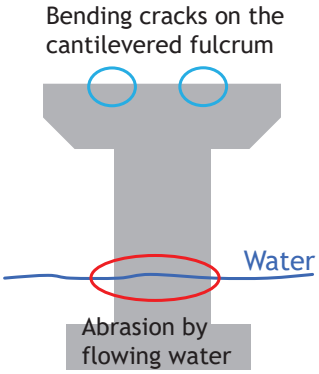
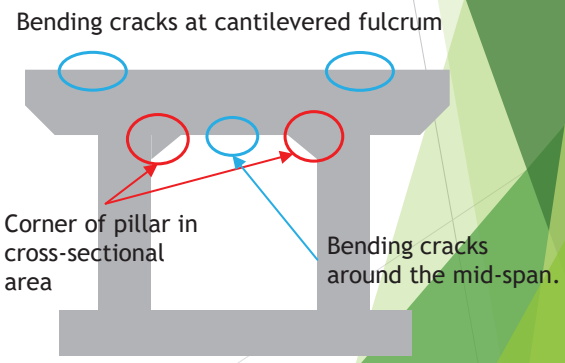
3. Key Points for Bridge Inspection

3.3 Areas to be inspected cont…

(3) Pier and coping beam





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References

- Information on slide 3, refer to Bridge Inspection Manual for ARBICS & PBC page 25.
- Information on slide 4, refer to Inspection Manual for Bridges page 21.
- Information on slides 5 & 6, refer to Bridge Inspection Manual for ARBICS & PBC pages 20 & 21.
- Information on slide 7, refer to Bridge Inspection Manual for ARBICS & PBC page 22.
- Information on slides 8 & 9, refer to Bridge Inspection Manual for ARBICS & PBC page 24.
- Information on slides 10-21, refer to Bridge Inspection Handbook pages 9-24.

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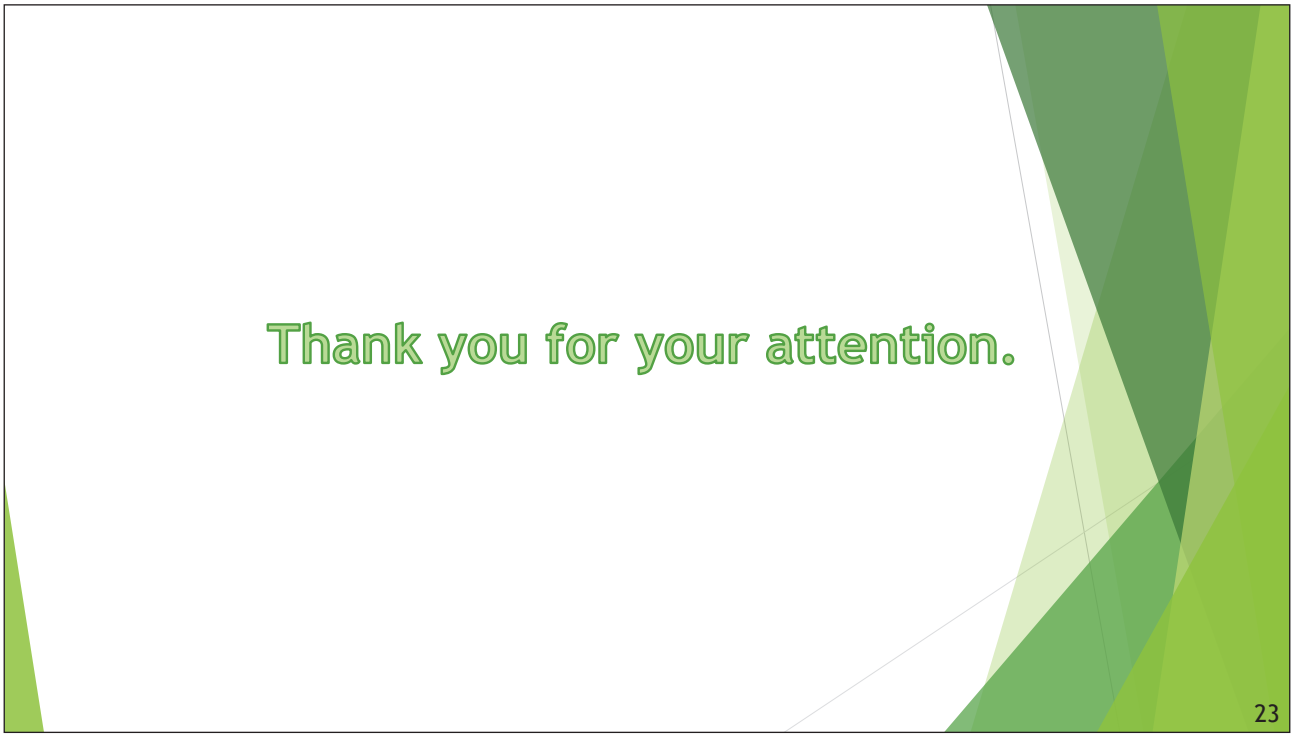

Thank you for your attention.
23

08-
DESTRUCTIVE TEST

1

CONTENTS

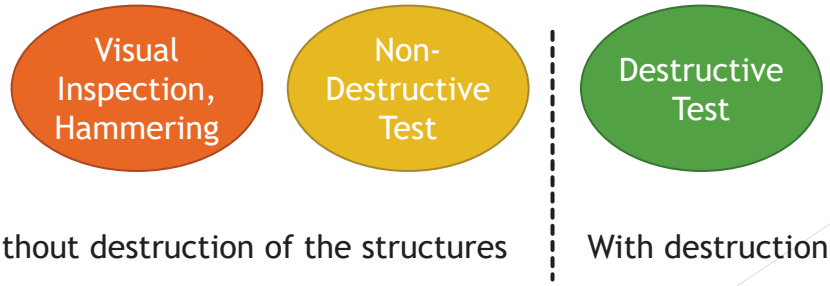
1. Types of Inspection Methods
2. What is a Destructive Test?
3. Types of Destructive Tests
   - 3.1 Core Sampling
   - 3.2 Chipping Concrete
   - 3.3 Drilling Concrete

   } for Concrete Structures
4. Restoration after Destructive Tests

2

1. Types of inspection methods

- There are two types of structural inspection methods.
- One is to survey the structure without damaging the structure, this method is known as non-destructive method (visual inspection).
- The other method is to locally destroy the structure to investigate it, such as taking concrete cores and testing them.



3

1. Types of inspection methods

1.1 The purpose of each inspection method

- For example, as concrete deteriorates, deformations become apparent on the concrete surface.
- Therefore, the first step of inspection is to inspect the surface condition visually and by hammering.

4

1. Types of inspection methods

1.1 The purpose of each inspection method cont…

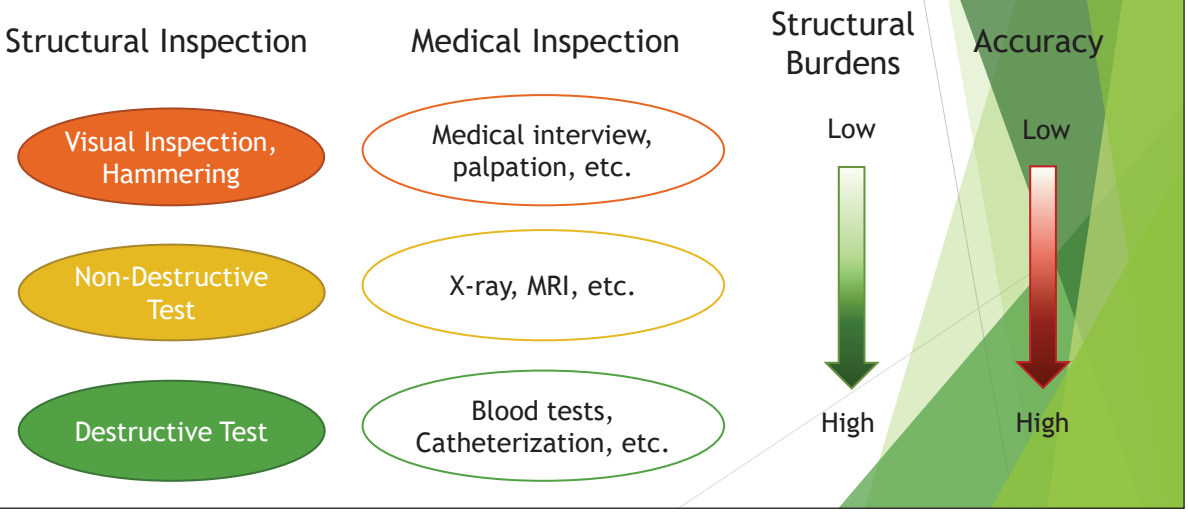
Non-Destructive Test

- This method is used when visual and acoustic inspections do not provide sufficient information.
- When performing non-destructive testing, the purpose, scope of application and the required measurement accuracy should be understood and clarified.

5

1. Types of inspection methods

1.2 The Contrast between Structural Inspection and Human Medical Inspection



2. What is a Destructive Test?

Destructive Test

- A small portion of the structure is extracted to investigate the physical and chemical properties and deteriorations of the concrete.
- This is performed when visual inspection, hammering and non-destructive testing do not provide sufficient information or when a more accurate information is required.

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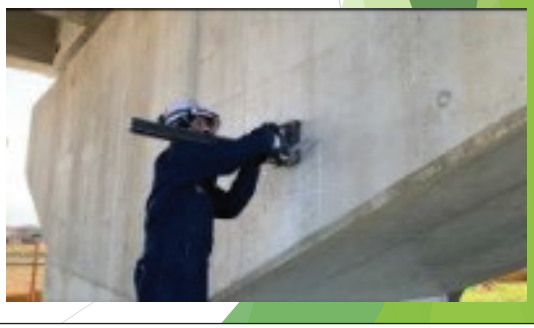
3. Types of Destructive Tests

3.1 Core Sampling

Objectives

- To conduct laboratory tests such as compressive strength tests using the cores taken from the structures.
- To observe the condition of interior of the structure using the cores.

Extraction of core



8

3. Types of Destructive Test

3.1 Core Sampling cont…

Factors to consider before core sampling

- The number of cores to be sampled
- Check on site if;
  - The cores can be collected safely or not
  - The core sampling machine can be installed or not
- Ensure the rebar in concrete is not cut off by clarifying the rebar arrangement before sampling

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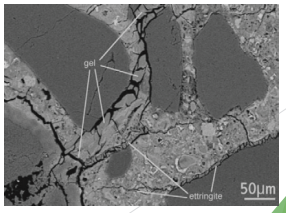
3. Types of Destructive Tests

3.1 Core Sampling cont…

Examples of utilization of sampled cores

- Compressive Test
- Static Modulus Test
- Carbonation Test
- Chloride Ion Content Test
- Microscopic Observation (for Alkali-Silica Reaction)
- Surface Observation

Compressive test



Microscopic observation

Carbonation test

10

3. Types of Destructive Tests

3.2 Chipping Concrete

Objectives

To check the following items;

- Condition of reinforcing bars in concrete
- Corrosion condition of reinforcing bar
- Rebar diameter
- Concrete cover thickness
- Carbonation depth

Items to consider

- The work shall be performed so as not to damage the reinforcing steel bars by electric drills, etc.

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3. Types of Destructive Tests

3.2 Chipping Concrete cont…

Examples of chipping concrete

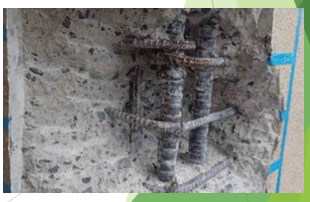
Chipping concrete

Rebar arrangement

Concrete cover thickness

Rebar diameter

Carbonation depth



Corrosion condition

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3. Types of Destructive Tests

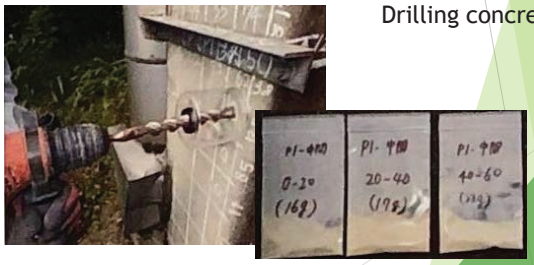
3.3 Drilling Concrete

Objectives

- Measurement of carbonation depth
- Sampling for chloride ion content test

Drilling concrete

Measurement of Carbonation Depth



Sampling for Chloride Ion Content Test

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4. Restoration after Destructive Test

- After destructive test, proper restoration shall be performed using non-shrinkage mortar or other repair materials.
- If restored in an improper manner, deterioration may progress from the areas destroyed during the survey.

Polymer cement



Careful Work

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References

- Information on this unit of competence, refer to Inspection Manual for Bridges chapter 7, pages 209-224.

09-
NON-DESTRUCTIVE TEST

1

CONTENTS

Concrete & Steel Structures

Steel Structures

Concrete Structures

2

1. What is Non-Destructive Test (NDT)?

- Non-Destructive Test is a type of inspection method that examines the condition of structures without destroying them.
- There are various methods of NDT depending on the structure. Although new methods have been developed to meet the needs of the times, some common NDT methods are introduced in this module.

3

2. Types of NDT

2.1 Visual Inspection

- It is a technique for detecting defects using the eye to ensure a structure is in a good condition.
- Inspectors visually view the condition of the bridge in detail, either by standing directly in front of the structure and looking at it or by using tools, like drones, pole cameras, etc, which can provide visual information to them remotely.

4

2. Types of NDT

2.1 Visual Inspection cont…

Acoustic inspection.

- This is a type of visual inspection where an inspector uses a hammer, chain drag, rolling bar or other tools to observe changes in sound pitch on the bridge components.
- Acoustic testing can be used to detect defects such as delamination, spalling, etc, in concrete structures.

5

2. Types of NDT

2.2 Ultrasonic Testing (UT)

- Ultrasonic waves are propagated inside the specimen and the size and shape of the flaw is estimated based on the strength and range of ultrasonic waves reflected from the flaw.

- It is applied on welds and members of steel structures such as steel frames and girders.
- It is applied to detect internal cracks in concrete structures

6

2. Types of NDT

2.2 Ultrasonic Testing (UT) cont...

Principle

- Ultrasonic Testing is a method of flaw detection in which ultrasonic waves emitted from an ultrasonic sensor (probe) are transmitted into a test piece and the condition of the test piece is measured by the state of reception of the reflected ultrasonic waves.

7

2. Types of NDT

2.2 Ultrasonic Testing (UT) cont...

Principle cont...

- The principle is as follows;
  i. Ultrasonic waves are emitted from the probe.
  ii. Ultrasonic waves propagate inside the test piece.
  iii. Ultrasonic waves are reflected from cavities or foreign bodies inside the test piece.
  iv. If there are no cavities or foreign bodies, ultrasonic waves are reflected from the opposite side.
  v. The reflected ultrasonic waves are received, the location of the defect is estimated by the time required, and size of the defect is estimated by the strength of the reflected waves.

8

2. Types of NDT

2.2 Ultrasonic Testing (UT) cont…

Pulse-reflectometry

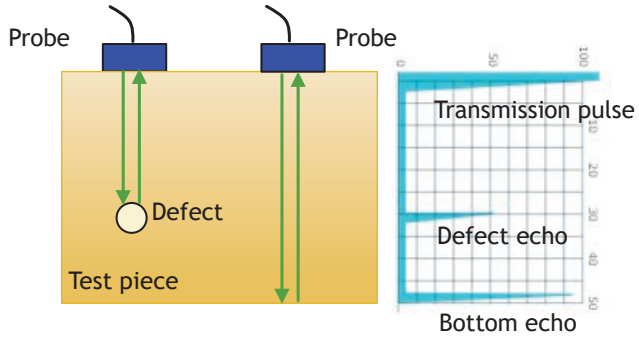
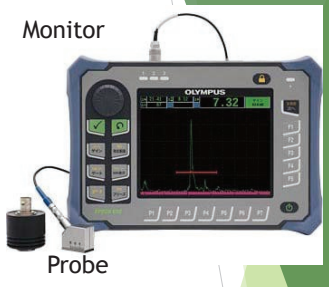


Fig. Diagram of the Test Principle



Echo size	Defect size
Return time	Defect location

10

2. Types of NDT

2.3 Infrared Thermography Testing (TT)

- The Infrared Thermography Testing detects defects based on the surface temperature of the structure.
- This is based on the fact that defects in the structure (voids, delamination, etc.) act as an insulating layer, during the daily fluctuations in surface temperature caused by solar radiation and temperature changes, there are time periods when the surface temperature difference occur between the defects and the sound areas.

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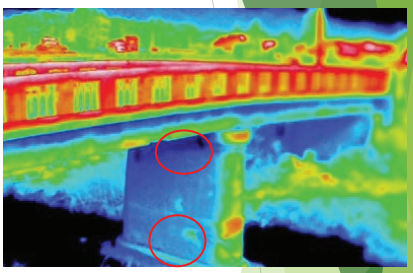
2. Types of NDT

2.3 Infrared Thermography Testing (TT) cont…

- The infrared camera produces the image shown in the figure.
- The image shows the difference in surface temperature and does not mean directly the existence of defects.
- Areas where there is a difference in temperature from the surrounding area are areas where damage is suspected even if there is no abnormality on the surface (Red circled areas).



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2. Types of NDT

2.3 Infrared Thermography Testing (TT) cont…

Features

i. Non-contact inspection from a distance is possible.
ii. The status of temperature distribution can be obtained as a thermal image.
iii. It is a screening survey method.
iv. Inspection may be difficult due to infrared reflections from the surrounding structures or shade.
v. Depending on the application, the time of day when inspections are possible may be limited to daytime only.

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2. Types of NDT

2.4 Magnetic-particle Testing (MT)

- The magnetic particle test is a non-destructive testing method with high sensitivity for detecting cracks on the surface of the specimen.
- When a ferromagnetic specimen that is expected to have cracks or other flaws is magnetized by an electromagnet and fine powder of ferromagnetic material (magnetic powder) is sprinkled on the surface of the test piece, the magnetic powder is adsorbed into the cracks or other flaws and a magnetic powder pattern appears.

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2. Types of NDT

2.4 Magnetic-particle Testing (MT) cont…

Principle

- When a ferromagnetic material is magnetized, leakage flux is generated in the outer space when there are defects in the surface layer that obstruct the magnetic flux.
- This method detects defects on the surface layer from the magnetic powder pattern adsorbed by this leakage flux.

Features

i. Applicable only to ferromagnetic materials attracted by magnets.
ii. Can detect defects on the surface and just below the surface.
iii. At least two magnetization operations in two directions are required to detect defects in all directions.
iv. Defect depth is not known.

16

2. Types of NDT

2.4 Magnetic-particle Testing (MT) cont…

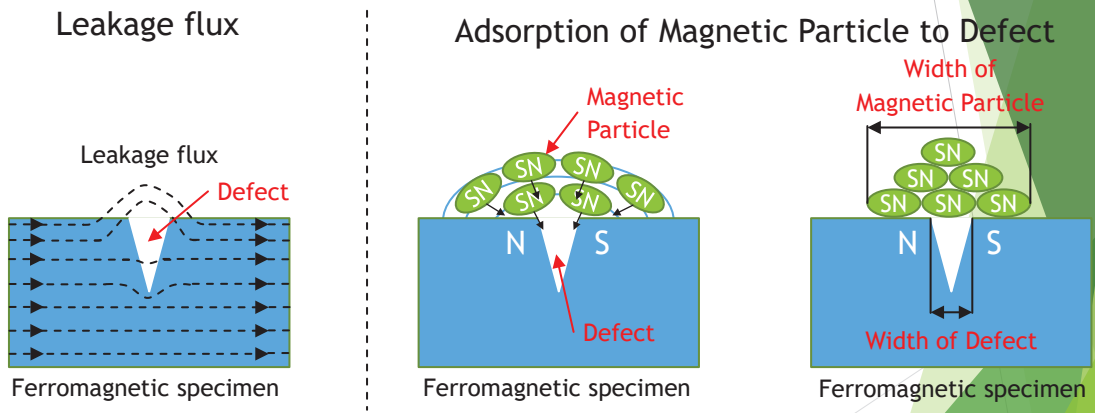

Fig. Diagram of Test Principle

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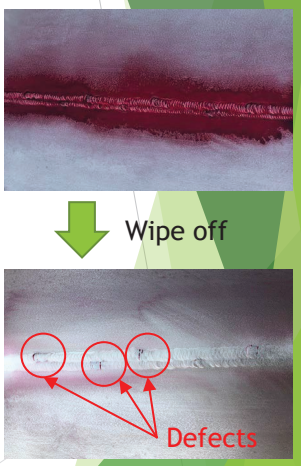
2. Types of NDT

2.5 Penetrant Testing (PT)

- The Penetrant Testing (PT) method is a testing method that uses a highly penetrating liquid that is applied on the surface of the material to be inspected, and after the liquid penetrates the crack, the excess liquid remains even after the washed off the surface.

NOTE:
Almost all materials, whether metallic or non-metallic, are subject to this method.



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2. Types of NDT

2.5 Penetrant Testing (PT) cont…

Principle

- This method utilizes capillary and perceptual phenomena to create a more magnified image of the appeared pattern so that the defects that are on the surface can easily be seen.

Features:

i. Applicable to both metallic and non-metallic materials as long as they are not porous.
ii. Defects that are hollow inside and open on the surface can be detected.
iii. Defects in all directions can be detected in a single operation.
iv. It is not possible to determine the width and depth of defects from the indication pattern.

20

2. Types of NDT

2.5 Penetrant Testing (PT) cont…

Remove oil, dirt, etc. from the inspection surface with a cleaning solution.

Apply osmotic solution and allow it to stand for osmosis time.

Surface seepage is removed with a washing-up liquid. Washable osmotic solution is removed with water.

Apply the developer. Scratches are enlarged and appear as an indicative pattern.

Fig. Diagram of the Test Principle

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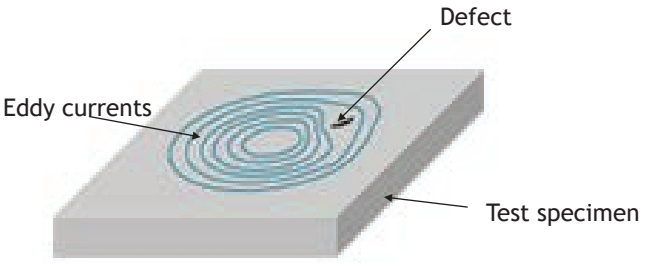
2. Types of NDT

2.6 Eddy Current Testing (ET)

- Eddy Current Testing (ET) is a testing method that detects defects by utilizing the disturbance of eddy currents generated inside a metal due to the magnetic field generated when an electric current is applied to a coil, which is disturbed by defects.



23

2. Types of NDT

2.6 Eddy Current Testing (ET) cont…

Principle

- When an alternating current (AC) is applied to a coil and the coil is brought close to the test piece, eddy currents are generated in the object.
- Since eddy currents are generated by avoiding surface defects such as cracks, the existence of a defect causes a change in the flow of eddy currents. In this testing, the change in eddy currents is used to determine the existence of flaws.

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2. Types of NDT

2.6 Eddy Current Testing (ET) cont…

Features:

i. No need to apply liquids such as osmotic solutions and developer for penetrant testing, the measurement area can be inspected without contaminating it.

ii. No post-treatment such as demagnetization for magnetic particle testing is required due to the use of weak electric currents.

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2. Types of NDT

2.6 Eddy Current Testing (ET) cont…

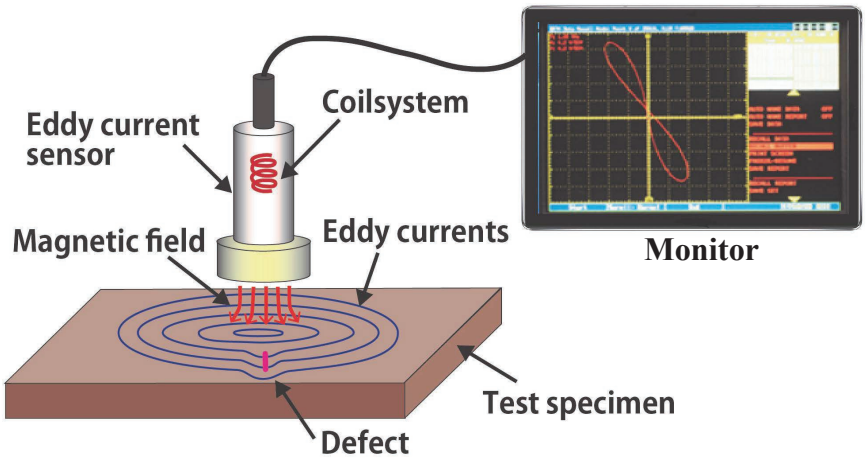

Fig. Test Principle Diagram

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2. Types of NDT

2.7 Rebound Hammer (Schmidt Hammer)

- The Rebound Hammer method is a method of measuring the strength of concrete by applying a blow to the concrete and measuring the strength of the reflection of the returned impact.
- This is the simplest method to measure (estimate) the strength of concrete without destroying it.

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2. Types of NDT

2.7 Rebound Hammer (Schmidt Hammer) cont…

Principle

- When the plunger of rebound hammer is pressed against the surface of the concrete, the spring- controlled hammer mass rebounds and the extent of such rebound depends upon the surface hardness of concrete
- Since the test is affected by gravity, it is necessary to compensate for the effect of the striking angle.

Features

- Measurements can be taken without damaging the structure.
- Lightweight equipment for simple and easy measurement.
- Easy to perform a large number of measurements.

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2. Types of NDT

2.7 Rebound Hammer (Schmidt Hammer) cont…

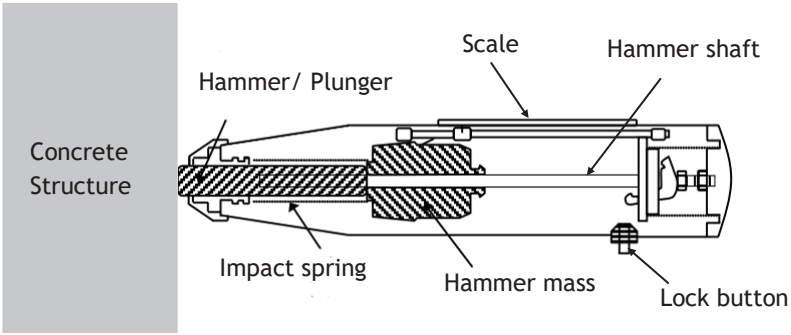

Fig. Diagram of the Internal Structure of the Rebound Hammer

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2. Types of NDT

2.8 Rebar Exploration

- The depth (cover thickness), location, direction and the quantity of reinforcing bars in a reinforced concrete structures are non-destructively surveyed by radar and electromagnetic induction methods.
- It is possible to survey for metals, plastics and cavities other than reinforcing bars.

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2. Types of NDT

2.8 Rebar Exploration cont…

Principle

- Electromagnetic waves are radiated from the surface towards the interior of the concrete.
- If there are materials inside the concrete with different dielectric constants from the concrete, such as rebars or cavities, the electromagnetic waves are reflected back at the boundaries.
- The position of the target object can be detected by receiving the returned reflected wave signal and processing the signal.

Features

- Measured objects: Rebar, PVC pipe, and Cavities in concrete
- Measurement depth: 5 to 200 mm

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2. Types of NDT

2.8 Rebar Exploration cont…

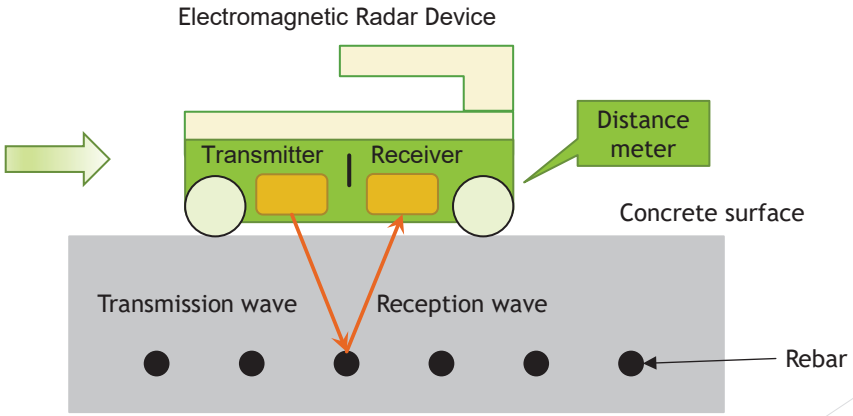

Fig. Diagram of Test Principle

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References

- Information on this unit of competence, refer to Inspection Manual for Bridges chapter 7, pages 168-208.

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BASIC INFORMATION
FOR ONSITE INSPECTION

1

CONTENTS

1. Inspection equipment
   - 1.1 Test hammer
   - 1.2 Crack scale
   - 1.3 Rebound hammer(Schmidt hammer)
   - 1.4 Pole camera
2. Inspection report

2

1. Inspection equipment

1.1 Test hammer

Hammer tapping test to identify swelling, spalling and cavity in concrete

- Existence of damages can be determined by the sound produced from the hammer tapping on the concrete surface.
- A booming/hollow sound indicates that there are damages like swelling or spalling, on the other hand, a high-pitched sound indicates no damages.
- Approximately, ¼ pound hammer is used for the inspection.
- Striking of the hammer is repeated in all directions at 200mm radius.

Hammer tapping

Hammer

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1. Inspection equipment

1.2 Crack Scale

Measurement of Crack width

- Crack width measurement is the most basic test before a detailed investigation is carried out on a concrete structure.
- The crack width on the surface of a concrete structure is measured using a crack scale.

Crack width measurement using a scale

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1. Inspection equipment

1.3 Rebound Hammer (Schmidt Hammer)

Objective

i. To investigate the deterioration of concrete over time (decrease in compressive strength)
   - The strength of concrete can be checked by squeezing the core (test piece) out of the structure and conducting a compression test, but this has the major disadvantage of damaging the structure.
   - For this reason, the Schmidt hammer is used for impact testing because it is relatively easy to perform without damaging the structure.
   - However, while it has the advantage of simplicity, it also has the disadvantage of somewhat low accuracy of measurement results.
   - The value from the test is just an estimate, not accurate.

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1. Inspection equipment

1.3 Rebound Hammer (Schmidt Hammer) cont…

Test procedure

i) Decide where to measure

- The measurement point should be a place where it is possible to secure a stance that can firmly catch the rebound of the hammer.
- When testing walls and columns, the height should be about 1.3m from the ground.
- An area with smooth concrete surface and no concrete defects shall be selected.
- A location at least 30mm away from the corner and with a concrete thickness of at least 100 mm shall be selected.

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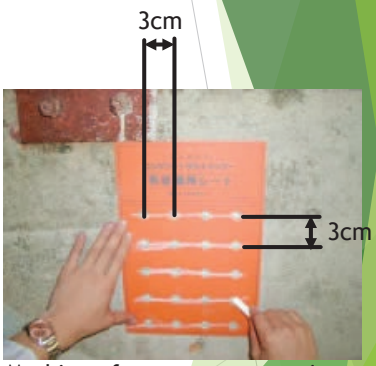
1. Inspection equipment

1.3 Rebound Hammer (Schmidt Hammer) cont…

Test procedure cont…

ii) Marking

- After deciding the measurement location, mark the 20 measurement points.
- Distance between each points shall be approximately 30mm as shown in the photo.



Marking of measurement points

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1. Inspection equipment

1.3 Rebound Hammer (Schmidt Hammer) cont…

Test procedure cont…

iii) Measurement

- Gently strike the measuring point with a Schmidt hammer.
- The Schmidt hammer should always strike at right angle to the concrete surface.
- When striking, do not recoil, but apply force gradually and press down slowly.
- The inspector should hold the Schmidt hammer in position to record the readings.
- The direction of the strike must also be recorded. This is necessary when estimating the compressive strength.

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1. Inspection equipment

1.3 Rebound Hammer (Schmidt Hammer) cont…

Test procedure cont…

iv) Calculation

- The Schmidt hammer measurement is not the final compressive strength value of concrete.
- To estimate the concrete strength, angle correction will be applied to the measured values, and the estimated concrete strength is calculated using the following equation.

$$Fc = (-18.0 + 1.27R_0)$$

where,

Fc :Estimated concrete strength (N/mm²)

R_0 :Hardness $(R + \Delta R)$

R : Mean value excluding singular values

ΔR : Angle correction

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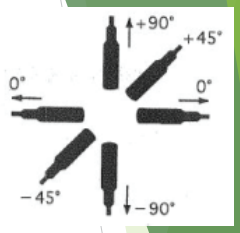
1. Inspection equipment

1.3 Rebound Hammer (Schmidt Hammer) cont…



Test procedure cont…

iv) Calculation cont…

ΔR : Angle correction

- Due to the internal structure of the Schmidt hammer (hammer mass inside), the horizontal strike (0°) is used as the standard.
- When testing upward (+90°), a value greater than the actual value will be displayed due to the influence of gravity , so the correction value ΔR should be subtracted from the degree of rebound (R value) obtained from the measurement.
- Conversely, if the test is performed downward (-90°), a lower value than the actual value will be displayed, so the correction value ΔR should be added to the degree of rebound (R value) obtained from the measurement.

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1. Inspection equipment

1.4 Pole camera

- Pole camera is used to inspect areas that can't be accessed by the inspectors due to height.
- It used for visual inspection using a camera mounted on a pole and connected to a phone or tablet via Bluetooth that act as control panel.

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2. Inspection Report

Inspection record

Objectives

i. To keep inspection data for future reference and planning.

ii. To record systematically and periodically the condition of the structure.

iii. To help in monitoring any changes in condition with time, thus providing early warning of problems.

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2. Inspection Report

Inspection record

The following steps will followed when writing an inspection report:

Step 1

- Record the information of the bridge i.e., bridge name, type of bridge, dimensions, components, material type, the year of construction, location point, name of the inspector and the date of inspection .

Step 2

- The background information indicating reason for carrying out the inspection.(whether Principal, Routine, Periodic or Emergency Inspection)

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2. Inspection Report

Inspection record

Step 3

- List all the defects observed and give their possible causes. Arranging them in the order from top most components of the superstructure to the lowest components of the substructure.
- Attach photos of the defects observed in each component.

Step 4

- Maintain list as step 3 but this time give possible countermeasure to be put in place. Give the dimension and the quantity of the works required.
- If possible give the best methodology to be used to repair the defects.

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2. Inspection Report

Inspection record

Step 5

- Give comments on the general condition of the bridge. Then sign and submit the report to the supervisor

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2. Inspection Report

Inspection forms

Attached in the appendix

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References

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11-
TYPES OF REPAIR

1

CONTENTS

2

1. Introduction to Bridge Defects & Repair

- Historically, maintenance of bridges in Kenya has been overshadowed by the need for new bridges. Prioritization and focus on construction of new bridges has resulted in neglect of maintenance of existing bridges.
- Defects in structures can result from many factors among them poor design, poor detailing, poor workmanship, structural failure, abnormal loading, chemical attack, foundation settlement, changes on the support or loading caused by scouring or siltation, failure of bearings or expansion joints and collision load.
- It is often difficult to establish the actual cause of any defect when the evidence from inspection is of limited nature. Many factors cause defects however, the original design and construction details would come in handy in determining the actual cause to facilitate the correct repair strategy.

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2. Types of Repair Works

- Maintenance are routine activities meant to prevent defects and prolong the life of bridges. Repairs are restoration work for when a bridge component gets broken, damaged or collapses.
- There are two types of maintenance and repair works namely; Minor Maintenance and Repairs and Major Repairs
- This module focuses on the Minor Maintenance and Repair Works.

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2.1 Minor Maintenance and Repairs

Introduction

- These are minor works that require basic tools and materials that are planned and performed on regular basis to maintain and preserve the condition of the structures.
- Types of Minor Maintenance and Repairs:
  - 2.1.1 Cleaning
  - 2.1.2 Touch-up painting
  - 2.1.3 Epoxy Coating on Cracks
  - 2.1.4 Patching/ Sectional Repair
  - 2.1.5 Removal of obstructions from structures openings
  - 2.1.6 Partial Replacement of Masonry Stone
  - 2.1.7 Partial Replacement of Gabion Wire Mesh and Stone

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2.1 Minor Maintenance and Repairs

2.1.1 Cleaning

Definition

- This is the removal of debris and all accumulated foreign materials from the entire bridge by hand sweeping, high-pressure water/air (blasting), shovel or mechanical devices.
- Cleaning of deck slab, main girders, bearings, drains and expansion joints is important before bridge inspection to enable proper observation of an element for detection of any damage and deterioration.
- The drainages must be cleaned regularly to prevent accumulation of water which may trigger rusting of the structural members.

Cleaning using water pressure

Cleaning using water pressure

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2.1 Minor Maintenance and Repairs

2.1.1 Cleaning cont…

Scope of Works

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.

ii. Bridge Deck Slab

All surface areas of the bridge deck should be cleaned, including the kerbs, expansion joints, drain pits and railings.

iii. Bridge Substructure

All areas under the superstructure should be cleaned, including the bearings, sidewall, pier caps and diaphragms.

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2.1 Minor Maintenance and Repairs

2.1.1 Cleaning cont…

Required Tools/ Equipment

No.	Tools/ Equipment	Purpose
1	Hand/Mechanical shovel	Removing debris
2	Ladder/Scaffold/Inspection vehicle	Access to high 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 and truck	Carting away debris
7	PPE	Protection of workers

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2.1 Minor Maintenance and Repairs

2.1.2 Touch-up Painting

Definition

- Touch-up painting is done to prevent corrosion. These works only cover localised areas where use of hand and power tools is the only feasible method.
- Larger areas where sand blasting cleaning can be justified, should be painted in accordance with the repainting procedure as described in major maintenance repairs in the manual.
- Anti-corrosion paint systems should be used for galvanised and heavily corroded steel surfaces.
- Ordinary selected patch paint such as aluminium paint is not suitable for galvanised surfaces

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2.1 Minor Maintenance and Repairs

2.1.2 Touch-up Painting cont…

Scope of Works

- 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.

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2.1 Minor Maintenance and Repairs

2.1.2 Touch-up Painting cont…

Materials Required

i. Aluminium Paint (locally available)
ii. Thinner
iii. Special Anti-corrosion Paint

Required Equipment/ Tools

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

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2.1 Minor Maintenance and Repairs

2.1.2 Touch-up Painting cont…

Work sequence

i. Scaffolding

- Scaffolding should be installed at the side of the structure prior to touch up painting.
- Inspection vehicle with scaffolding device can also be utilized at locations where accessibility is difficult, such as bridges with high elevation or at deep river crossings.

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2.1 Minor Maintenance and Repairs

2.1.2 Touch-up Painting cont…

Work sequence cont…

ii. Preparation of the Steel Surface

- Depending on severity of corrosion on the members, the old coating film rust is removed with disc grinder, scraper or wire brush, revealing the steel surface.
- Sharp ridges and deep narrow grooves or pits shall be removed from the steel surface using power grinder.
- Each coat shall not be more than the maximum film thickness recommended by the manufacturer.

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2.1 Minor Maintenance and Repairs

2.1.2 Touch-up Painting cont…

Work sequence cont…

iii. Touch-up Painting

The paint components shall be:-

- Mixed properly and applied in accordance with the manufacturer's instructions.
- Applied immediately after surface preparation, preferably within 4 hours.
- 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 of the system should not be less than 125 micrometres (Aluminium paint) and 500 micrometres (Anti-corrosion paint).

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2.1 Minor Maintenance and Repairs

2.1.3 Epoxy Coating on Cracks

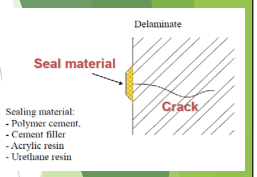
Definition

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

This method is generally applied to:-

- ❖ Cracks of **width less than 0.3mm**.
- ❖ Cracks on vertical or horizontal surfaces of concrete structures.

- ➢ Such cracks are sealed with polymer cement or other materials in order to protect the concrete structures from ingress of water and other harmful materials.
- ➢ This method is sometimes applied as a temporary repair measure.



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2.1 Minor Maintenance and Repairs

2.1.3 Epoxy Coating on Cracks cont…

Application criteria

- ➢ As a protective or preventive measure, epoxy coating should be applied on surfaces of concrete structures, with cracks of less than 0.3 mm width, regardless if crack formation is structural or non-structural, and has no adverse effect on the structure.
- ➢ However, it is difficult during routine maintenance to evaluate whether the crack is stable or developing due to such factors as carbonation, chlorination, corrosion, overloading of structure, insufficient reinforcement or inadequate concrete cover.
- ➢ There is need for continuous monitoring of the cracks

Required Materials

i. Epoxy Sealant

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2.1 Minor Maintenance and Repairs

2.1.3 Epoxy Coating on Cracks cont…

Work Sequence

i. *Preparation of Concrete Surface (cleaning of cracks)*
All cracks and surrounding surfaces shall be thoroughly cleaned using clean, oil-free compressed air.

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

iii. *Monitoring of Crack width*
The cracks coated with sealant shall be monitored by the Engineer to determine if the cracks are progressing or not.

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2.1 Minor Maintenance and Repairs

2.1.4 Patching/ Sectional Repair

Description of repair method

- This repair is performed to restore small areas where sound concrete is damaged by either spalling, scaling, honeycombing or impact.
- This method does not require formwork or utilizes minimum formwork.
- The patch thickness is limited to a maximum depth of **100mm.**

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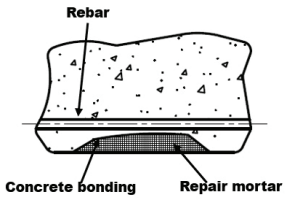
2.1 Minor Maintenance and Repairs

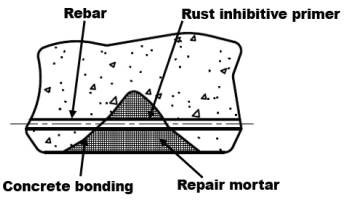
2.1.4 Patching/ Sectional Repair cont…

Types of patching

There are two types of patching; **Type A** is for defects without exposed rebars having defective widths of up to 300 mm and depth up to 50 mm, while **Type B** is applied to surfaces with exposed rebars with defective width between 300 mm and 600 mm, and up to 100 mm depth



Type A



Type B

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2.1 Minor Maintenance and Repairs

2.1.4 Patching/ Sectional Repair cont…

Types of patching cont…

Type A	Type B
Applicable to surfaces without rebar exposure	Applicable to surfaces with rebar exposure but depth shall not exceed 50% of the total depth.
Routine Maintenance Method	A Major Maintenance Method
Involves the application of either Portland cement mortar or polymer cement mortar	Involves the application of concrete

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2.1 Minor Maintenance and Repairs

2.1.4 Patching/ Sectional Repair cont…

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.
- Polymer Cement - (PCM Powder, PCM Emulsion)
- Concrete nails
- Bonding agent to concrete (epoxy Bonding)
- Clean water

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2.1 Minor Maintenance and Repairs

2.1.4 Patching/ Sectional Repair cont…

Required Equipment and Tools

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

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2.1 Minor Maintenance and Repairs

2.1.4 Patching/ Sectional Repair cont…

Plastering method

- Plastering is one of the most popular conventional repair methods. After section preparation, the material is filled into the section using a spatula, trowel, etc.
- The number of layers may vary depending on the material characteristics and depth of the repair section.

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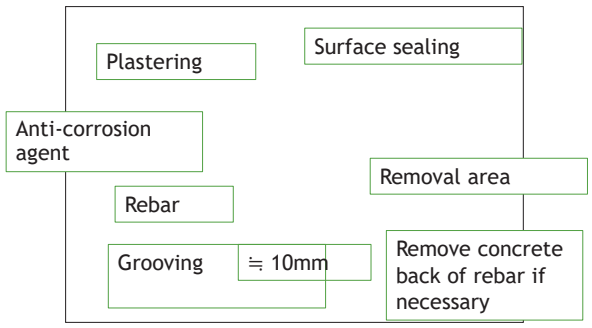
2.1 Minor Maintenance and Repairs

2.1.4 Patching/ Sectional Repair cont…

Plastering method cont…



Preparation of repair section

To fill repair material with spatula, trowel

24

2.1 Minor Maintenance and Repairs

2.1.5 Removal of Obstructions from Structures Openings

Definition of work

- This is the removal of driftwoods around substructures and disposing them to a designated area.

Accumulated driftwood obstructing the free flow of water

25

2.1 Minor Maintenance and Repairs

2.1.5 Removal of Obstructions from Structures Openings

Application criteria

- Driftwoods and debris lodged on the inlets and outlets of the 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 failure.
- This should be carried out once a year or after occurrence of floods when necessary.

Required Equipment and Tools

- ❑ Power saw
- ❑ Inspection vehicle
- ❑ Back hoe
- ❑ Dump truck
- ❑ Electric saw

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2.1 Minor Maintenance and Repairs

2.1.5 Removal of Obstructions from Structures Openings

Work Sequence

i. Large driftwoods are cut at the site and properly disposed to a designated disposal area.

ii. Burning of driftwoods or debris is not permitted within the road reserve.

iii. If there is difficulty in accessing the driftwood and debris piled around the substructure, scaffolding may be necessary. Inspection vehicle with scaffolding device can be utilized also for the works.

27

2.1 Minor Maintenance and Repairs

2.1.6 Partial Replacement of Masonry Stone

Definition

- This is the restoration of missing stones from masonry slope protection.

Missing stone on a masonry protection wall

28

2.1 Minor Maintenance and Repairs

2.1.6 Partial Replacement of Masonry Stone

Application criteria

- 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 risks of slope failure.

Required Materials

i. Stones
ii. Cement
iii. Fine aggregates
iv. Water

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2.1 Minor Maintenance and Repairs

2.1.6 Partial Replacement of Masonry Stone

Work Sequence

The following activities shall be done as instructed:

i. Remove all unsound, imperfect or loose stones and mortar joint, panel, etc.

ii. Compact the substrata as preparation of the base.

iii. Prepare the slope line carefully at the same level.

iv. Install new masonry stone according to alignment and dimensions.

30

2.1 Minor Maintenance and Repairs

2.1.6 Partial Replacement of Masonry Stone

Work Sequence

v. Lay the stones in full bed of mortar, with joints completely filled with mortar and shoved into place. Stone must be laid and anchors must be installed in accordance with the instructions. Coursing and mortar joints must be done.

➢ Where new stone masonry is placed to the existing masonry wall, joints shall be partially or completely set. Exposed surface of the existing stone masonry shall be cleaned with wire brush and lightly moistened so as to attain best possible bonding with the new work.

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2.1 Minor Maintenance and Repairs

2.1.7 Partial Replacement of Gabion Wire Mesh and Stone

Definition

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

Dilapidated gabion mesh

32

2.1 Minor Maintenance and Repairs

2.1.7 Partial Replacement of Gabion Wire Mesh and Stone

Application criteria

- 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.
- 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.

33

2.1 Minor Maintenance and Repairs

2.1.7 Partial Replacement of Gabion Wire Mesh and Stone

Work sequence

i. The damaged area is replaced by installation of new gabion wire according to the set standards.

ii. The damaged wire mesh section shall be removed from the gabion boxes.

iii. The damaged section of the mesh shall be replaced using similar wire mesh as directed by the Engineer.

iv. The gabion box shall be filled with additional stone if required.

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2.1 Minor Maintenance and Repairs

2.1.7 Partial Replacement of Gabion Wire Mesh and Stone

Work sequence cont…

v. The stones should have 150mm minimum dimension and 300mm maximum dimension. The sides shall be packed first using large pieces and then the internal using smaller pieces.

vi. The joints in the gabion box shall be stitched together with binder wire. If the Engineer directs, the exposed surfaces of the gabion boxes may be grouted with cement.

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References

- Information on this unit of competence, refer to Bridge Repair Manual chapter 3, pages 79-96.

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MAJOR REPAIRS TO CONCRETE STRUCTURES

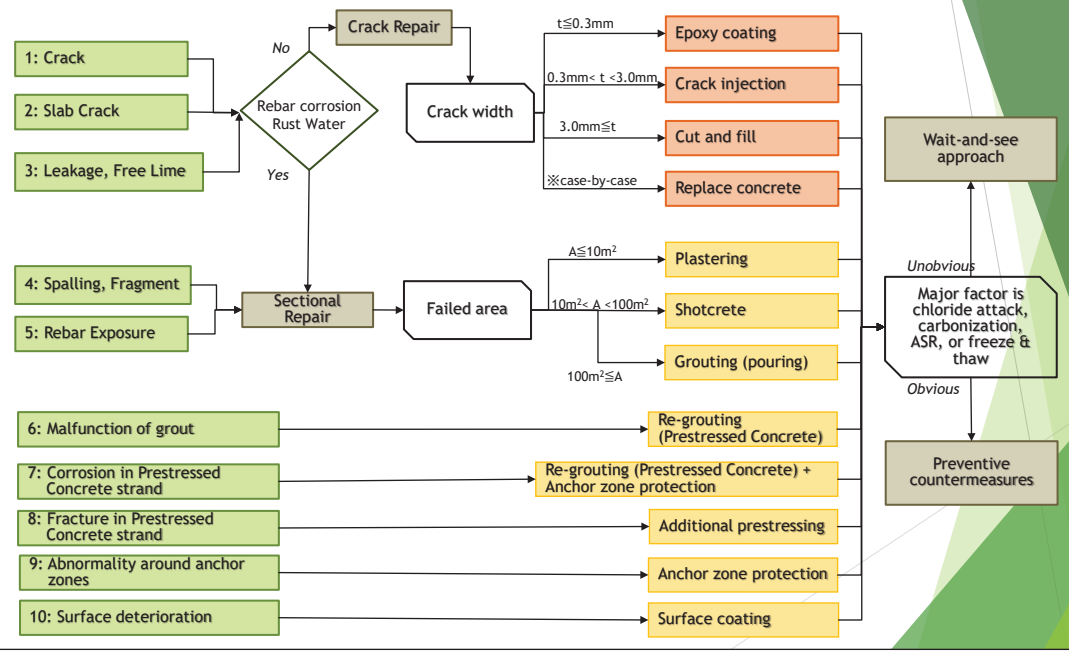
1

CONTENTS

1. Selection of Repair Methods
2. Major Repair Works

2

1. Selection of Repair Methods



3

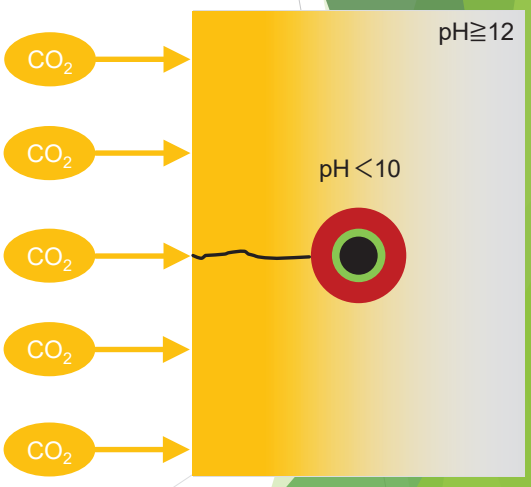
1. Selection of Repair Methods

1.1 Carbonation

- The chemical reaction decreases the pH:

  $CO_2 + H_2O + Ca(OH)_2 \rightarrow CaCO_3 + 2H_2O$

- The passive state film is broken exposing the rebar.
- Rebar corrodes and expands up to 2.5 times causing cracks to occur.



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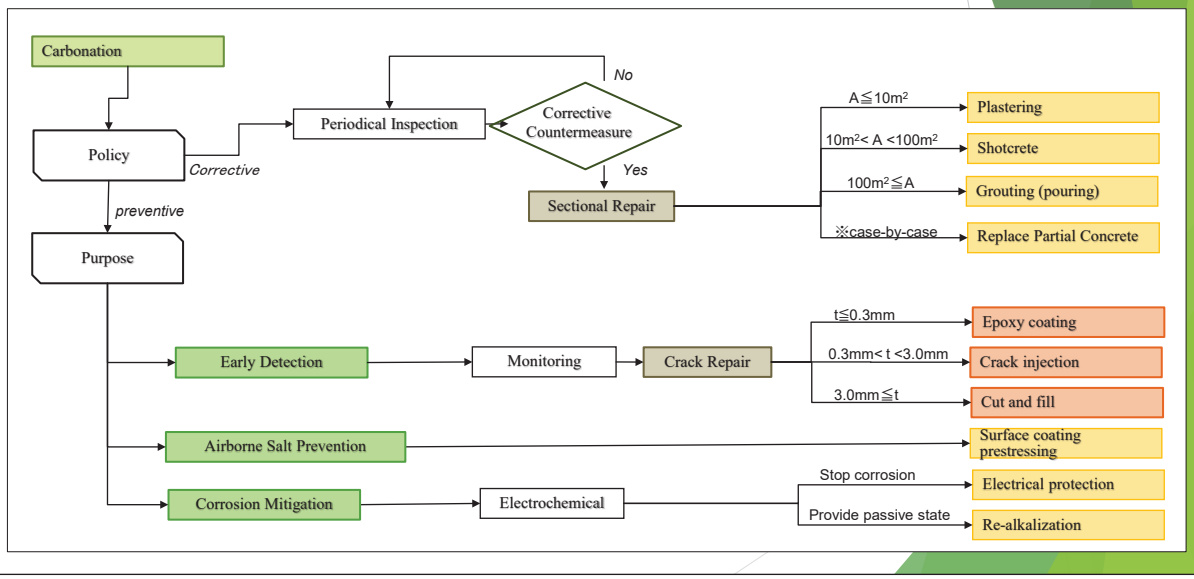
1. Selection of Repair Methods

1.1 Carbonation cont…



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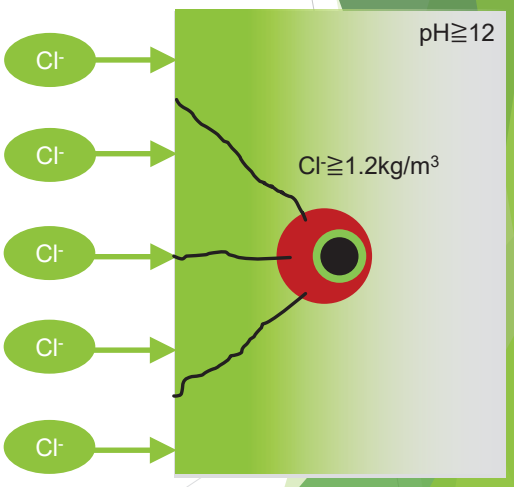
1. Selection of Repair Methods

1.2 Chloride Attack

- Chloride ions ingress into concrete.
- Passive state film is partially broken.
- Rebar corrodes and expands up to 2.5 times exerting pressure on the concrete cover.
- Cracks occur. Cracks accelerate chloride ion ingress and rebar corrosion.



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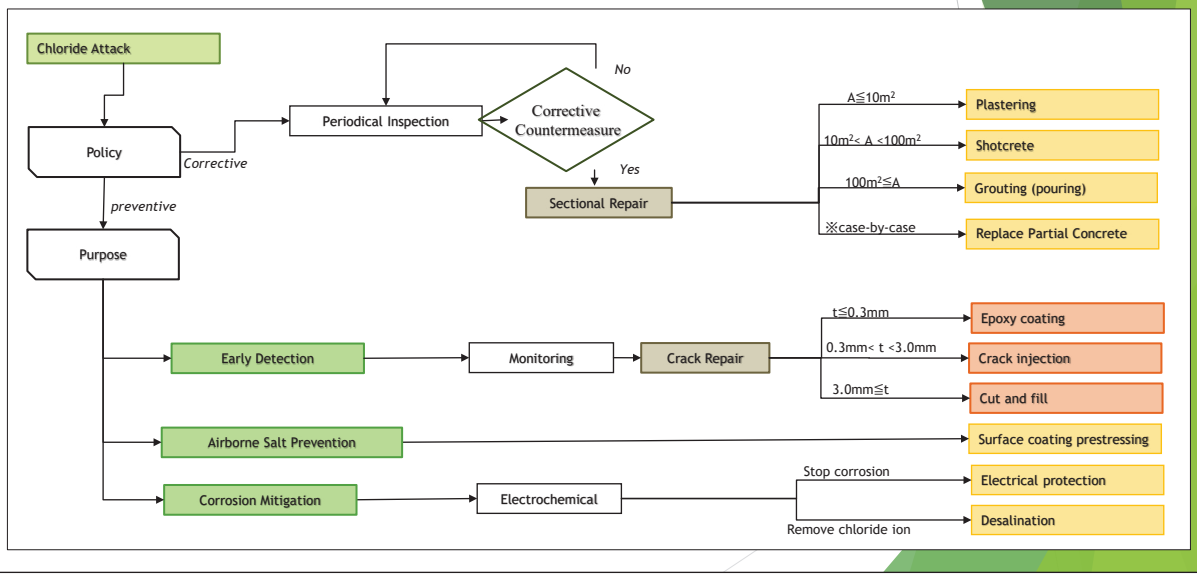
1. Selection of Repair Methods

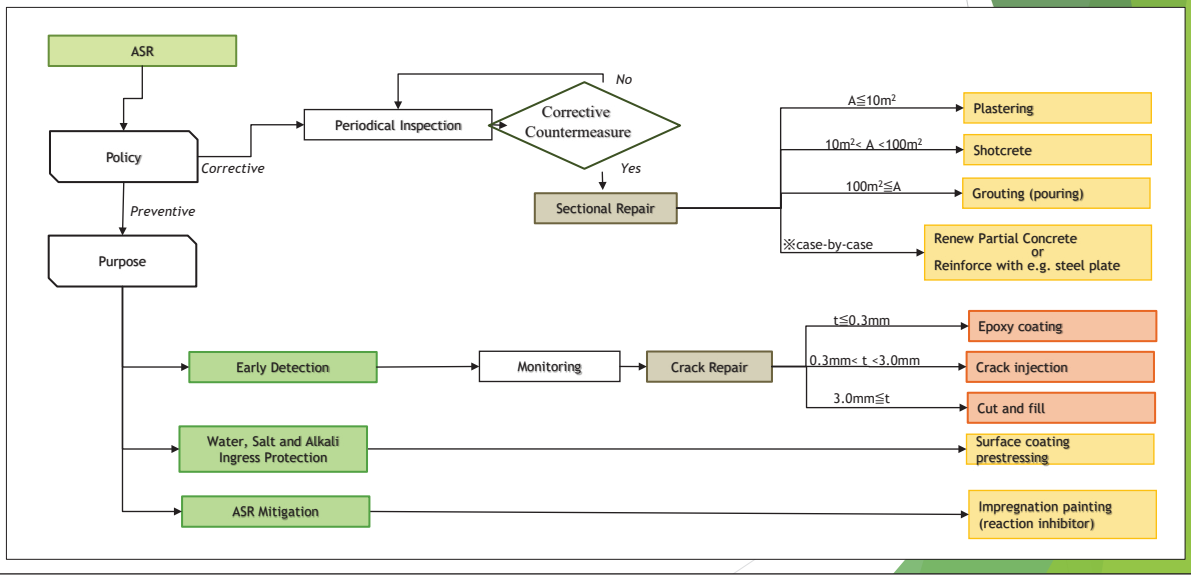
1.2 Chloride Attack



7

1. Selection of Repair Methods

1.3 Alkali-Silica Reaction (ASR)



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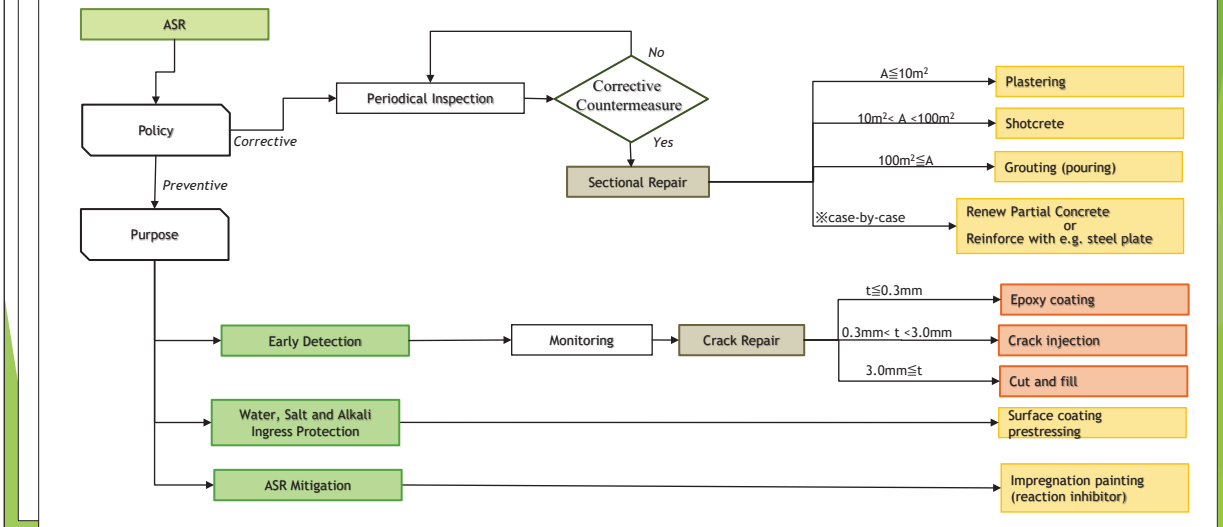
1. Selection of Repair Methods

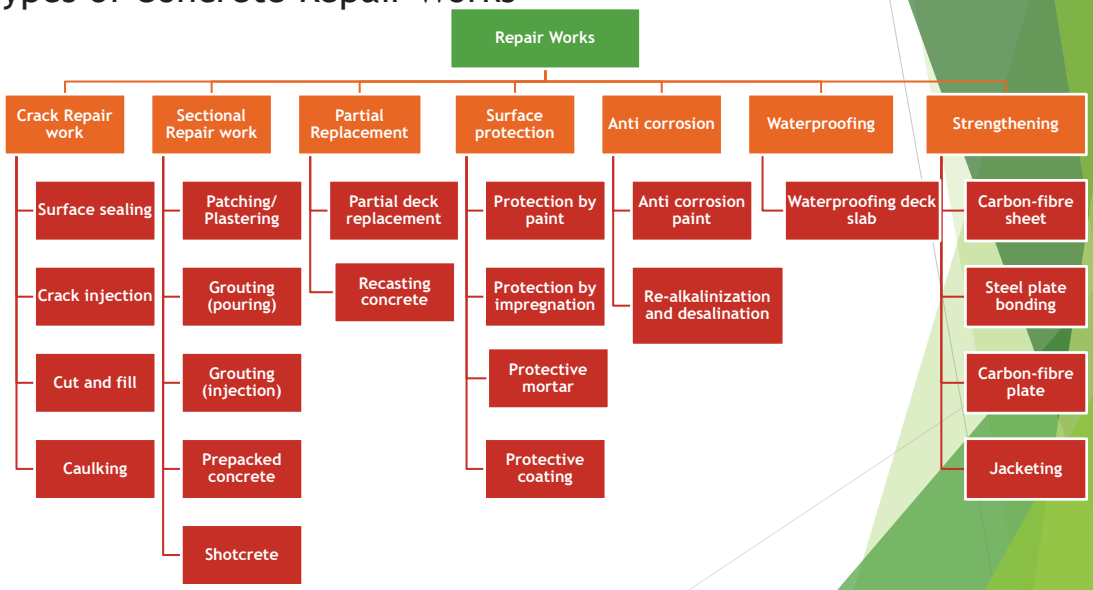
1.4 Freeze-Thaw



9

2. Repair Works

Types of Concrete Repair Works



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2. Repair Works

2.1 Crack Repair

Definition

- This is a method of repairing cracks on concrete structures and is capable of restoring concrete strength.
- The works include preparation of concrete surface, insertion of pipe fittings bonded with adhesion, injection of epoxy, curing and conduction performance test.

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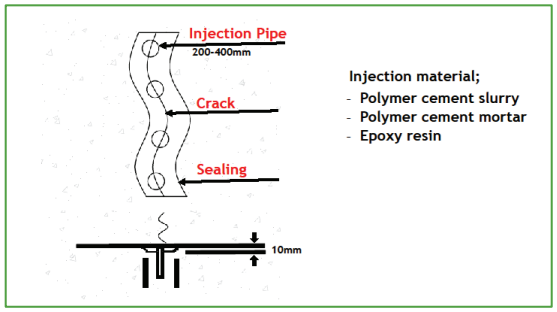
2. Repair Works

2.1 Crack Repair cont…

a) Surface sealing method

This is the process of placing an adhesive sealant into cracks on the concrete surface, preventing the infiltration of moisture and non-compressible materials into the concrete.



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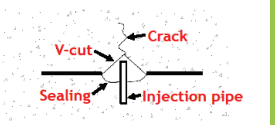
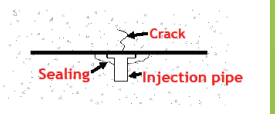
2. Repair Works

2.1 Crack Repair cont…

b) Crack injection method

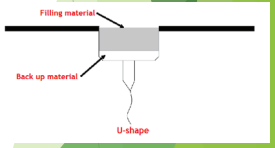
- Pressure is used to inject epoxy resin or polymer cement paste into the cracks to restore water-tightness and to protect the concrete structure from the ingress of harmful materials such as chloride ions.
- This method is inappropriate for developing cracks.





c) Cut and fill method

- Polymer cement mortar or epoxy mortar is filled in U-shape cut groove to recover water-tightness and to protect the concrete structure from the ingress of harmful materials such as chloride ions.



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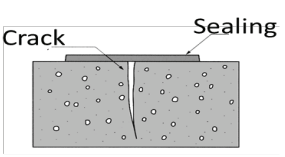
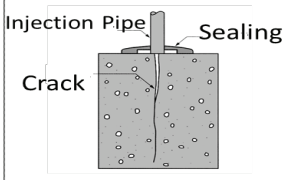
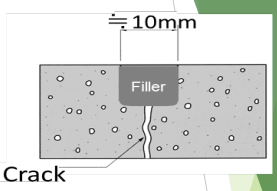
Photos of Crack Repair Works

	Surface sealing Work	Crack injection work	Cut and filling work
Schmatic diagram			
Magnitude	0.2mm or less	About 0.2～1.0mm	1.0 mm or more
Crack proceeding	Small		Large


Surface sealing work


Epoxy injection work


Cut & Fill work

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2. Repair Works

2.1 Crack Repair cont…

d) Caulking

- Caulking involves treating of active cracks as movement joints by repairing them with flexible sealants.
- The sealant is generally installed in wide recess cut along the crack.
- For selection of sealant material, crack movement is calculated taking into account the applied loads shrinkage and temperature variations.

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2. Repair Works

2.1 Crack Repair cont…

d) Caulking

Cleaning Cracks

Preparing grooves for Caulking

Drilling of holes and fixing injection pipes

Curing of Injected Material

Injecting the Epoxy Grout

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2. Repair Works

2.2 Sectional Repair Work

Definition

- This method involves the restoration of small areas where sound concrete is damaged by spalling, scaling, honeycombing or impact.

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2. Repair Works

2.2 Sectional Repair Work

a) Plastering/ Patching

- A method of repairing concrete surface damaged by spalling or delamination using cement mortar.
- Patching are of two types;
  - **Type A**: Patching applied on surfaces without exposed rebars
  - **Type B**: Patching applied on surfaces with exposed rebars

Removing loose particles

Applying Epoxy Bonding Coats

Placing Mortar

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2. Repair Works

2.2 Sectional Repair Work

b) Grouting (pouring) method

- This grouting method is the pouring of flowable repair material into the formed section.
- When the thickness of repair section is over 100mm, then prepacked concrete method is recommended.
- Equipment used for this method is small and the work is easy making this method applicable for all concrete structures where installation of scaffolding is available.
- Unfilled spaces or shrinkage gaps can be observed near the pouring mouth of grout material and the upper side of the repair section. In order to reduce these situations, the repair section should be well considered before pouring.

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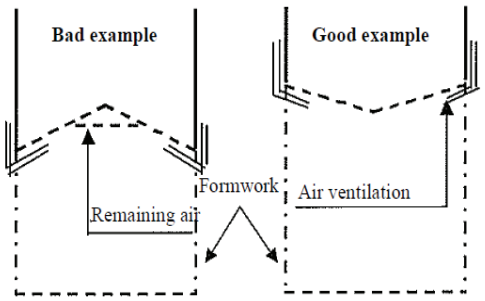
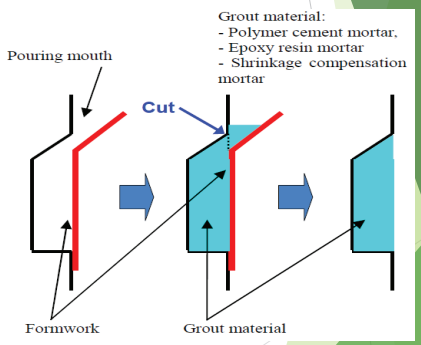
2. Repair Works

2.2 Sectional Repair Work

b) Grouting (pouring) method cont…





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2. Repair Works

2.2 Sectional Repair Work

c) Grouting (injection) method

- This grouting method is the injection of flowable repair material into the formed section.
- If the thickness of repair section is over 100mm, then the prepacked concrete method is recommended.
- Grout material is filled from the lower side of the repair section upwards using a mortar pump. Due to this filling procedure, void-less repair concrete section can be made.

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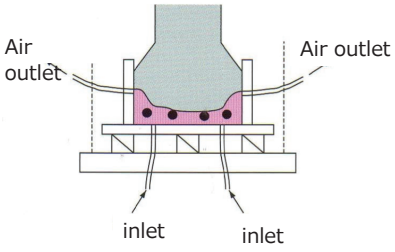
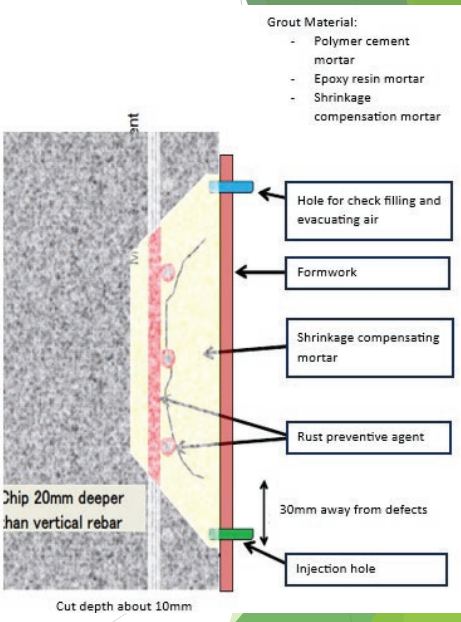
2. Repair Works

2.2 Sectional Repair Work

c) Grouting (injection) method cont…





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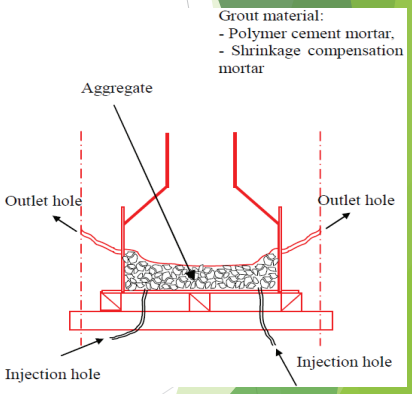
2. Repair Works

2.2 Sectional Repair Work

d) Prepacked concrete method

- Before grouting, the aggregate is arranged inside the formwork then the grout is injected by pressure using a mortar pump.
- This method is recommended when the depth of repair section is greater than 100mm
- After the injection, concrete is formed.



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2. Repair Works

2.2 Sectional Repair Work

d) Prepacked concrete method cont…

Removal of girder concrete

Cutting of deteriorated rebars and adding new rebars

Grouting Mortar after setting formwork

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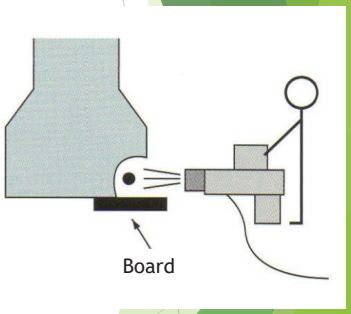
2. Repair Works

2.2 Sectional Repair Work

e) Shotcrete method

- Shotcrete method is the spraying of mortar or concrete to the repair section using compressed air.
- This method is normally selected for repair of vertical and overhead surfaces.



There are two types of shotcrete method;

- Dry shotcrete
- Wet shotcrete.

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2. Repair Works

2.3 Partial Replacement

a) Partial Deck Replacement

- This is carried out to replace a portion of the concrete that has been severely damaged due to corrosion of rebars, honeycombs, water leakages etc.
- Replacement generally involves removal of the deteriorated concrete, cleaning up the substrate and reinforcement, setting up formwork and replacement with new concrete.
- If the bridge cannot be closed due to traffic during repair, it is advisable to use fast-setting mortar instead of Portland cement concrete.

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2. Repair Works

2.3 Partial Replacement

a) Partial Deck Replacement cont…

Removal of deteriorated deck slab

Preparation of old concrete and Rebar and applying bonding agent

Casting new concrete

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2. Repair Works

2.3 Partial Replacement

b) Recasting Concrete

Conventional method

- This method involves casting the damaged area by placing concrete or grouting mortar on a formwork, it is usually most suitable for severely damaged concrete or for largely damaged areas with densely spaced rebars.
- This method is applied to achieve the following; protection against ingress, moisture control, concrete restoration, structural strengthening, physical resistance, resistance to chemicals, restoring passivity, increasing resistivity, cathodic control, cathodic protection and control of anodic areas.

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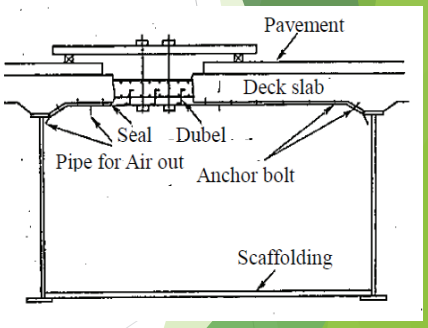
2. Repair Works

2.3 Partial Replacement

b) Recasting Concrete

Conventional method

- When concrete section is removed/ dropped, re-casting of concrete with formwork can be done.
- The damaged concrete section is removed but the anchor part of rebar should remain. Then, additional rebar may be arranged subject to the degree of damage.



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2. Repair Works

2.3 Partial Replacement

c) Fast Setting Mortar for Continued Deck Slab

- Fast setting mortar is a blend of ordinary and specialised cements, high quality graded aggregates and unique combination of polymers and admixtures and is used in continued deck slab connections where Reinforced Concrete Deck Girder (RCDG) bridges are to be constructed.
- The works generally involve complete removal of defective concrete and its adjacent surfaces to its full depth, setting formworks, cleaning the existing rebars(and placing additional rebars) and placing fast setting mortar.

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2. Repair Works

2.3 Partial Replacement

c) Fast Setting Mortar for Continued Deck Slab cont…

Placement of additional rebars and cleaning

Applying epoxy bonding material

Pouring mortar from lower part to upper part

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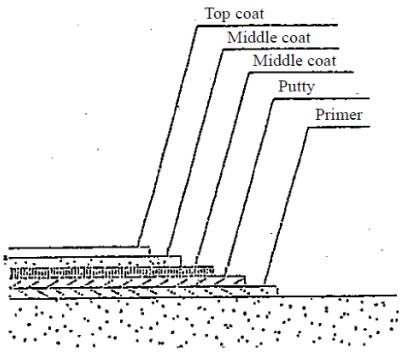
2. Repair Works

2.4 Surface Protection

a) Surface protection by paint

- Surface protection work is to protect the concrete from the ingress of water, carbon dioxide and oxygen by applying a coating paint or impregnation agent.
- Concrete surface is cleaned and treated. Subsequently the unevenness of concrete surface is rectified.
- Thereafter the finishing layer is applied.

Depending on required function, number of layers, type of material, thicknesses of layer shall be determined.



Conventional paint (coating) system

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2. Repair Works

2.4 Surface Protection cont…

b) Surface protection (impregnation agent) method

- Impregnation agents enhance the retention of the alkalinity and densify the concrete surface zone. This limits ingress of water and/ or chloride ions into the concrete surface to recover/improve the strength of concrete surface zone.
- The application of impregnation agents is easier than that of conventional concrete surface paint (coat) system.
- The dryness of concrete surface before application of the agent is very important.

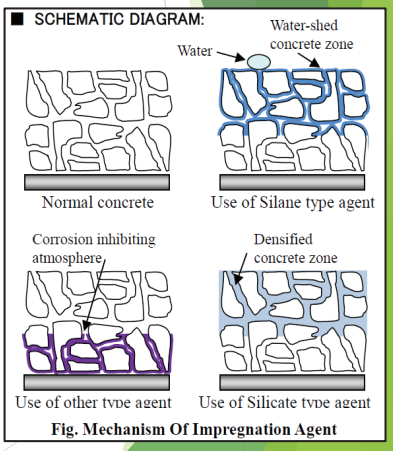

Fig. Mechanism Of Impregnation Agent

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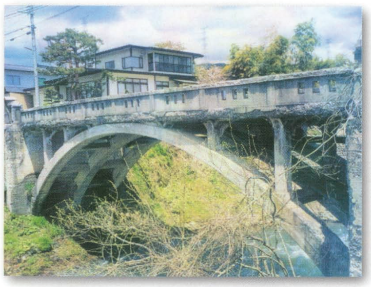
2. Repair Works

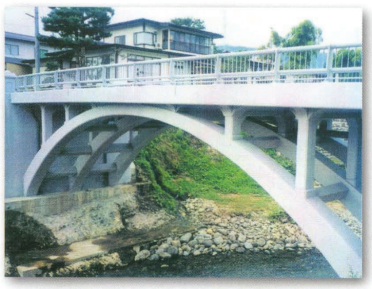
2.4 Surface Protection cont…

b) Surface protection (impregnation agent) method cont…

Example

- Blocking the entry of damage factors such as CO2, chloride ion, exhaust gas, water, etc.


Before Surface Sealing Work


After Surface Sealing Work

34

2. Repair Works

2.4 Surface Protection cont…

c) Protective mortar

- Concrete Bridges located in the coastal areas deteriorate due to salt attack, protective mortar made from polymer cement with lithium nitrate which is effective against chloride ions is used.
- 1mm thickness of protective mortar is applied to the surface of concrete member for preventive maintenance and 6mm thickness of protective mortar applied to the surface of concrete member with severe deteriorations.

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2. Repair Works

2.4 Surface Protection cont…

c) Protective mortar cont…

Prepare Surface

Mixing right proportions of cement powder and emulsion

Applying mortar using trowel or brush

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2. Repair Works

2.4 Surface Protection cont…

d) Protective Coating

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

Application of protective coating

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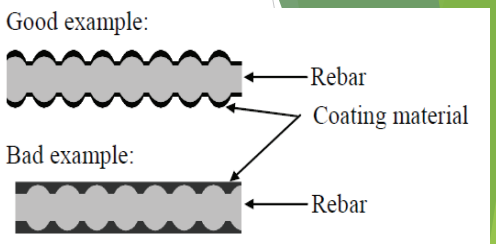
2. Repair Works

2.5 Anti-Corrosion

a) Anti-corrosion paint method

- This method consists of removal of rust and application of the anti corrosive paint (coat) on the damaged rebar.
- Depending on the causes of rust on the existing rebar, expected circumstances and repair conditions, the use of this method should be considered.



Application by brush

After application of anticorrosion paint

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2. Repair Works

2.5 Anti-Corrosion cont…

b) Re-alkalization and desalination method

- This method consists of arrangement of external electrode on the concrete surface and power distribution of direct current (DC) between the external electrode and steel bar in the existing concrete for impregnating alkaline solution into the concrete (Re-alkalization method) or removing chloride ion from the deteriorated concrete (Desalination method).
- Since both methods require provision of electrolyte solution from outside of the existing concrete, an electrolyte solution holding material shall be arranged.

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2. Repair Works

2.5 Anti-Corrosion cont…

b) Re-alkalization and desalination method cont…

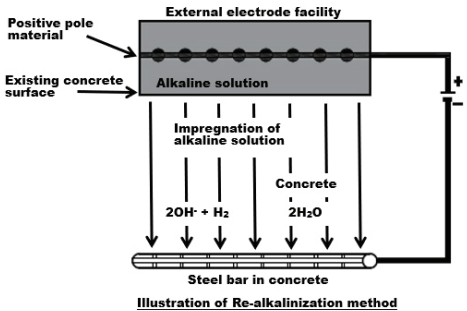

Illustration of Re-alkalinization method

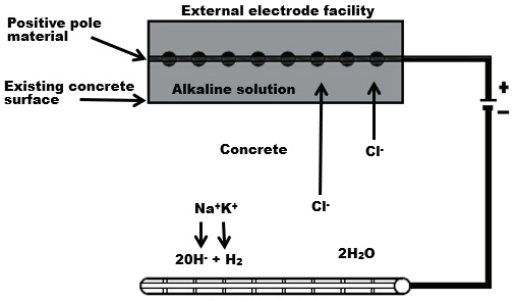

Illustration of Desalination method

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2. Repair Works

2.6 Waterproofing

a) Waterproofing the deck slab

- This is the application of impervious material layer on concrete which prevent ingress of water hence making the structure watertight.
- After installation of the waterproofing layer apply a wearing course.
- Two types of liquids are used to waterproof the deck slab:
  - Rubberized Membrane Type and
  - Asphalt Compound Membrane Type.

Rubberized Membrane Type

Asphalt Compound Membrane Type

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2. Repair Works

2.6 Waterproofing

a) Waterproofing the deck slab cont…

- This method involves construction of impervious layer using a membrane sheet or bituminous paint on the concrete surface in order to prevent ingress of water into the concrete.
- Waterproofing method is also targeted to stop water leakage with the application of waterproof cement or other similar materials.
- After installation of the waterproofing layer apply a wearing course.

Construction of waterproof layer using membrane sheet on concrete deck slab.

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2. Repair Works

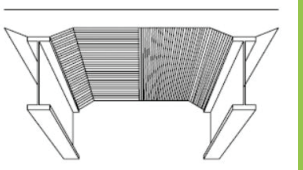
2.7 Strengthening

a) Carbon Fibre Sheet Bonding

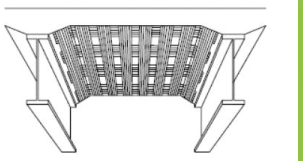
- Carbon fibre sheet is used to enhance the load bearing capacity of the concrete deck slab and extend its service life.
- It's a combination of carbon fibre reinforcing material and adhesive resin such as epoxies and other materials.

There are two arrangement types of Carbon Fibre Sheets i.e.,

- Continuous arrangement
- Grid Arrangement.



Continuous Arrangement



Grid Arrangement

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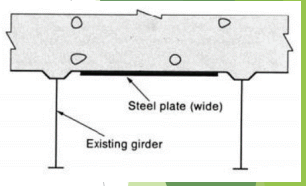
2. Repair Works

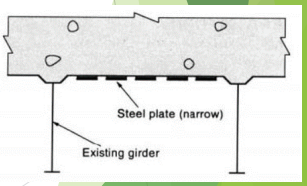
2.7 Strengthening

b) Steel Plate Bonding

- This is a technique of bonding steel plates to concrete deck slab or girder using epoxy adhesive material to enhance their load carrying capacity.
- In girders, steel plate is bonded with epoxy resin at the bottom or side face of the existing girders.
- There are two types of steel plate bonding for deck slab;
  - Wide plate for strengthening the slab in main reinforcing bar and distribution bar directions.
  - Narrow plate for strengthening the slab in one direction only



Wide Plate Type



Narrow Plate Type

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2. Repair Works

2.7 Strengthening

c) Carbon Fibre Sheet/ Plate Bonding

- Carbon Fibre Plate/sheet is used to strengthen a girder increasing its ultimate loading capacity and serviceability load capacity.
- The end quarter lengths (L/4) of the concrete girder shall consist of woven Carbon Fibre Sheet reinforcing layers bonded to the concrete surface with epoxy.
- The middle half length (L/2) of the concrete girder shall consist of Carbon Fibre Plate.

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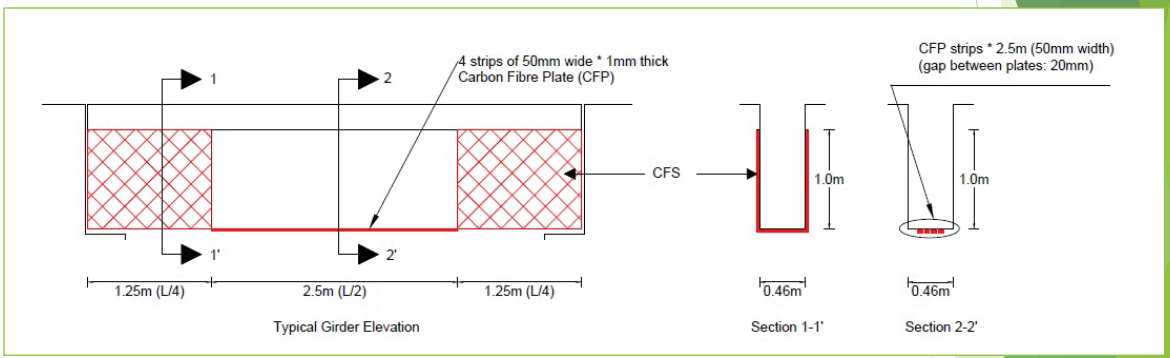
2. Repair Works

2.7 Strengthening

c) Carbon Fibre Sheet/ Plate Bonding cont…



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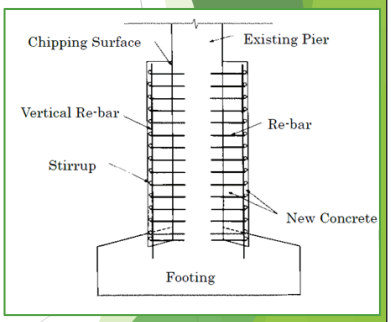
2. Repair Works

2.7 Strengthening

d) Jacketing with Concrete.

- Jacketing is a method of structural retrofitting and strengthening mainly applied to the substructure components.
- It is used to increase the load bearing capacity or to restore structural integrity of a member.
- The following jacketing methods can be used;
  - Reinforced Concrete jacketing
  - Steel jacketing
  - Fibre reinforced polymer jacketing
  - Glass fibre reinforced polymer jacketing
  - Hybrid jacketing
  - Shape Memory Alloy Wire jacketing



Reinforced concrete jacketing

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References

- Information on this unit of competence, refer to Bridge Repair Manual chapter 3, pages 97-151.

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Thank You

13-
MAJOR REPAIRS
TO STEEL STRUCTURES

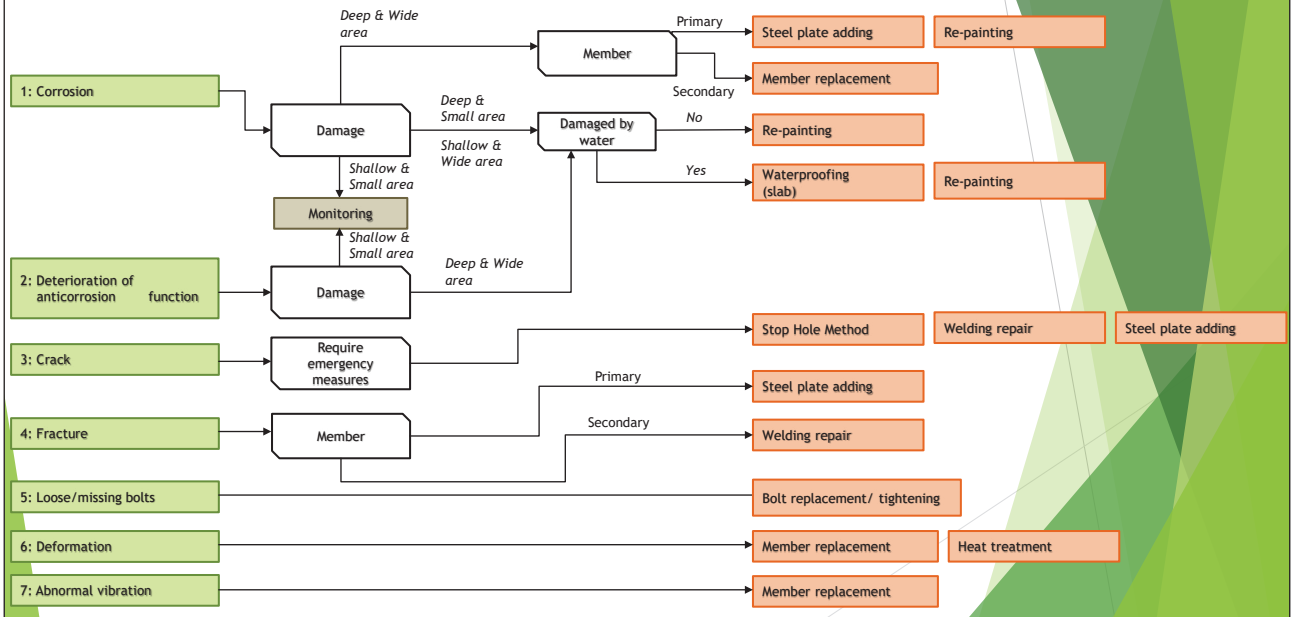
1

CONTENTS

1. REPAIR METHOD SELECTION
2. REPAIR WORKS

2

1. Repair method selection



Note: Concrete slab or other members that are constructed by concrete, refer to concrete repair presentation.

3

2. Repair Works

2.1 Corrosion

2.1.1 Typical Corrosion Protection Works

a) Weathering steel

- When an appropriate amount of alloy elements such as copper, chromium, and nickel are added to ordinary steel, and the steel is subjected to moderate dry and wet cycles in the atmosphere, a dense rust layer (protective rust) is formed on the steel surface.

This controls the corrosion speed and inhibits subsequent rust growth. Unlike ordinary steel, this steel can be used without painting.

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2. Repair Works

2.1 Corrosion cont…

2.1.1 Typical Corrosion Protection Works cont…

b) Thick Anti-corrosion Coating/Painting

- In addition to applying a thick coat of paint to extend the service life of the bridge, the coating is designed to withstand severe corrosive environments by using a paint that retains the steel's anti-corrosive properties for a long period of time.
- The overall paint film thickness should be 200 μm or more.

Composition of Thick Anticorrosion Coating

Highest quality paint composition

5

2. Repair Works

2.1 Corrosion cont…

2.1.1 Typical Corrosion Protection Works cont…

c) Galvanization

- The steel is immersed in a zinc bath to form a layer of iron-zinc alloy and a layer of zinc on the surface of the steel material.
- The zinc layer forms a dense passive film in the air and inhibits the depletion of zinc, thereby preventing corrosion of the steel.
- However, it should be noted that in severe environments where the plating is subjected to splashes of seawater, the expected passive film is not formed and the galvanization wears out quickly, resulting in progressive corrosion.

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2. Repair Works

2.1 Corrosion cont…

2.1.1 Typical Corrosion Protection Works cont…

d) Metallic Spray

- Zinc, aluminum, or their alloys are melted and sprayed on the steel surface to form a film that physically adheres to the steel surface and these metals, which prevents corrosion of steel through the environmental barrier effect and sacrificial corrosion protection effect of the metal film.
- It is often used to prevent corrosion of bearings.

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2. Repair Works

2.1 Corrosion cont…

2.1.2 Corrosion Repair Works

a) Repainting

- This is the application of a new coat of paint. The service life of steel structures could be expected to exceed 50 years if its surface is kept in good protection using suitable paint coating.
- If corrosion occurs, repainting is the only effective method for restoration of steel structures.

The surface is prepared by:

i. Sandblasting
ii. Grinding/brushing
iii. Cleaning
iv. Filling of voids
v. Painting

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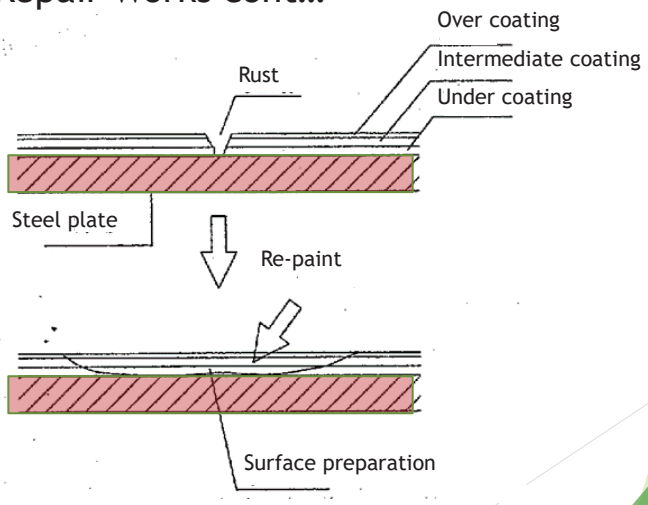
2. Repair Works

2.1 Corrosion cont…

2.1.2 Corrosion Repair Works cont…

a) Repainting



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2. Repair Works

2.1 Corrosion cont…

2.1.2 Corrosion Repair Works cont…

a) Repainting

10

2. Repair Works

2.1 Corrosion cont…

2.1.2 Corrosion Repair Works cont…

b) Anti-corrosion paint

- This is the application of anti-corrosion paint to protect solid metal surfaces and in some occasions various non-metals.
- As a minimum coating requirement, the total special anti-corrosion paint weight should exceed 1.0kg/m² for two coats.


Before surface preparation


By hand scraper


By electric scraper

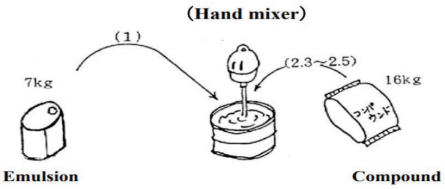

After completed surface preparation

2. Repair Works

2.1 Corrosion cont…

2.1.2 Corrosion Repair Works cont…

b) Anti-corrosion paint cont…




1st layer painting by spray gun


after completed 2nd painting

Shaded finish (blue color as example in above photo) can be applied as top coating for aesthetics purpose only, if required

2. Repair Works

2.1 Corrosion cont…

2.1.2 Corrosion Repair Works cont…

c) Steel Plate Adding

- This is the strengthening of the lower flange section of steel girders using steel plates.
- Steel girders near the sea shores/ coastal areas are prone to corrosion which leads to section loss at the bottom flanges and sections near the bearings.
- The existing bottom flanges with section loss are 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.

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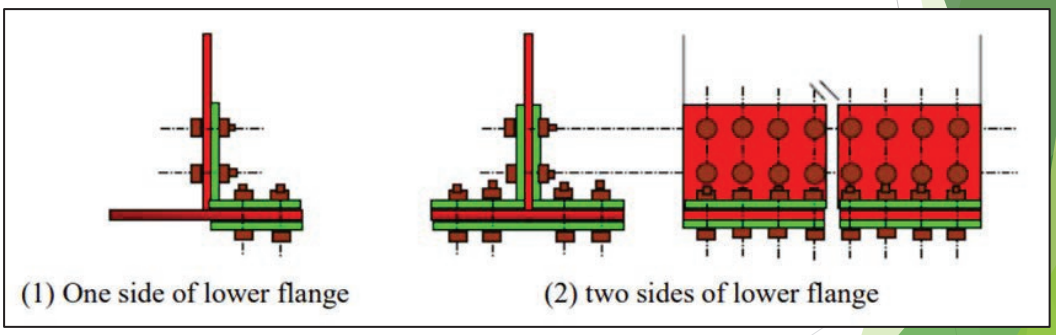
2. Repair Works

2.1 Corrosion cont…

2.1.2 Corrosion Repair Works cont…

c) Steel Plate Adding



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

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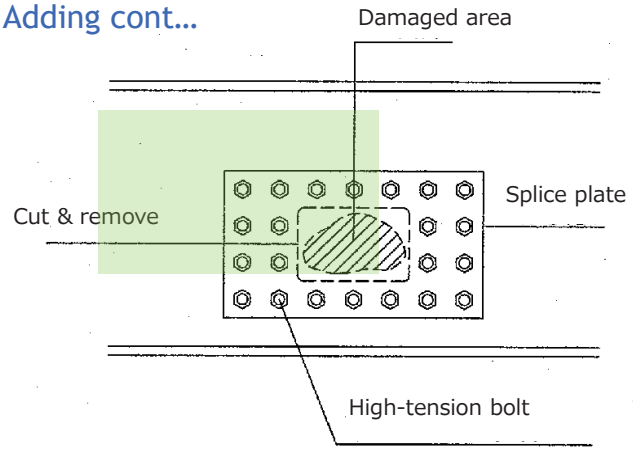
2. Repair Works

2.1 Corrosion cont...

2.1.2 Corrosion Repair Works cont...

c) Steel Plate Adding cont...



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2. Repair Works

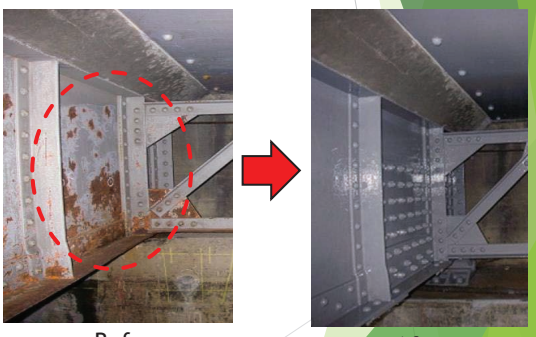
2.1 Corrosion cont...

2.1.2 Corrosion Repair Works cont...

c) Steel Plate Adding cont...

Note:

- Rusted areas to be cleaned first before steel addition process is started.
- After adding steel plate, paint the whole area to protect against corrosion.



Before

After

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2. Repair Works

2.1 Corrosion cont…

2.1.2 Corrosion Repair Works cont…

c) Steel Plate Adding cont…

- Steel Plate Adding Process

Damaged section

Prepared section

Steel plate added to the section

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2. Repair Works

2.1 Corrosion cont…

2.1.2 Corrosion Repair Works cont…

d) Member replacement method

- This is the replacement of a damaged (corroded) member with a new one.

Before

After

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2. Repair Works

2.2 Deterioration of anti-corrosion function

a) Repainting

- This is the application of a new coat of paint to a steel surface that was already painted. The paint layers can deteriorate with time depending on the environmental conditions or age.
- The paint layer may peel off, leaving the steel surface exposed making it vulnerable to corrosion.
- It is advisable to repaint the whole area in order to restore the anti-corrosion function.

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2. Repair Works

2.3 Cracking

a) Stop Hole Method

- 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 as shown in the pictures.
- This method is applied as an emergency measure before applying a permanent solution.

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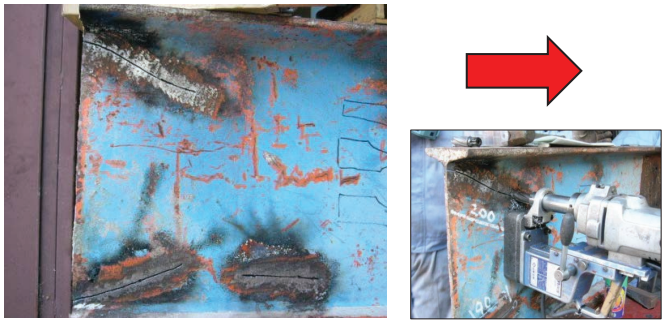
2. Repair Works

2.3 Cracking

a) Stop Hole Method cont…

Before



After

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2. Repair Works

2.3 Cracking cont…

b) Welding Method

- This method is used to repair cracked or fractured steel members.
- Welding is a method of joining two members that are either cracked or fractured.

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2. Repair Works

2.3 Cracking cont…

c) Steel Plate Adding

- Steel plate adding method can also be used to repair steel members that are cracked or fractured.
- Steel plate is added to leverage on the strength that was lost when the member was cracked or fractured.
- The plate can be added either by welding or bolts.
- The procedure is the same as described in the repair for corrosion.

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2. Repair Works

2.3 Cracking cont…

c) Steel Plate Adding

Damaged Section


Repaired Section

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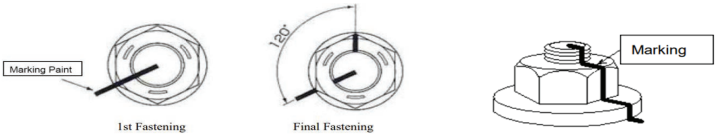
2. Repair Works

2.4 Loose/Missing Bolts

a) Tightening/Retightening of High-Tension Bolts

- This refers to replacing of missing and severely corroded or retightening of loosened High-Tension Bolt connection for steel structures.
- The procedure for tightening and retightening of HTB is well elaborated in the Bridge Repair Manual.



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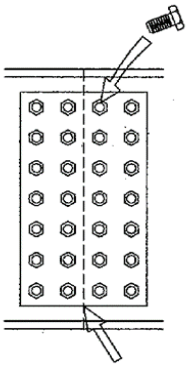
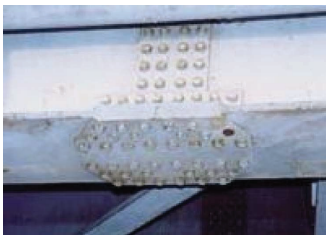
2. Repair Works

2.4 Loose/Missing Bolts

a) Tightening/Retightening of High-Tension Bolts cont…



Be aware of backside corrosion.



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2. Repair Works

2.5 Deformation

a) Heat Treatment Method

- A method where a deformed member is heated then reshaped to original form.

Before | Heating | Treatment

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2. Repair Works

2.6 Abnormal Vibration

a) Carbon Fibre Plate (CFP) Bonding

- This involves application of CFP to steel bridge surface with epoxy resin adhesive as a bonding agent.
- This repair method provides the same function as the additional steel plates.
- In order to restore the lost strength, CFP is installed at the portion of existing steel where section loss is more than 20%.
- This repair method is further supplemented by repainting or by applying anti-corrosion coating.

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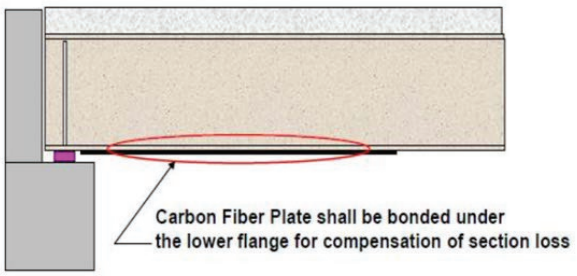
2. Repair Works

2.6 Abnormal Vibration

a) Carbon Fibre Plate (CFP) Bonding cont…



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References

- Information on this unit of competence, refer to Bridges Repair Manual chapter 3, pages 152-174.

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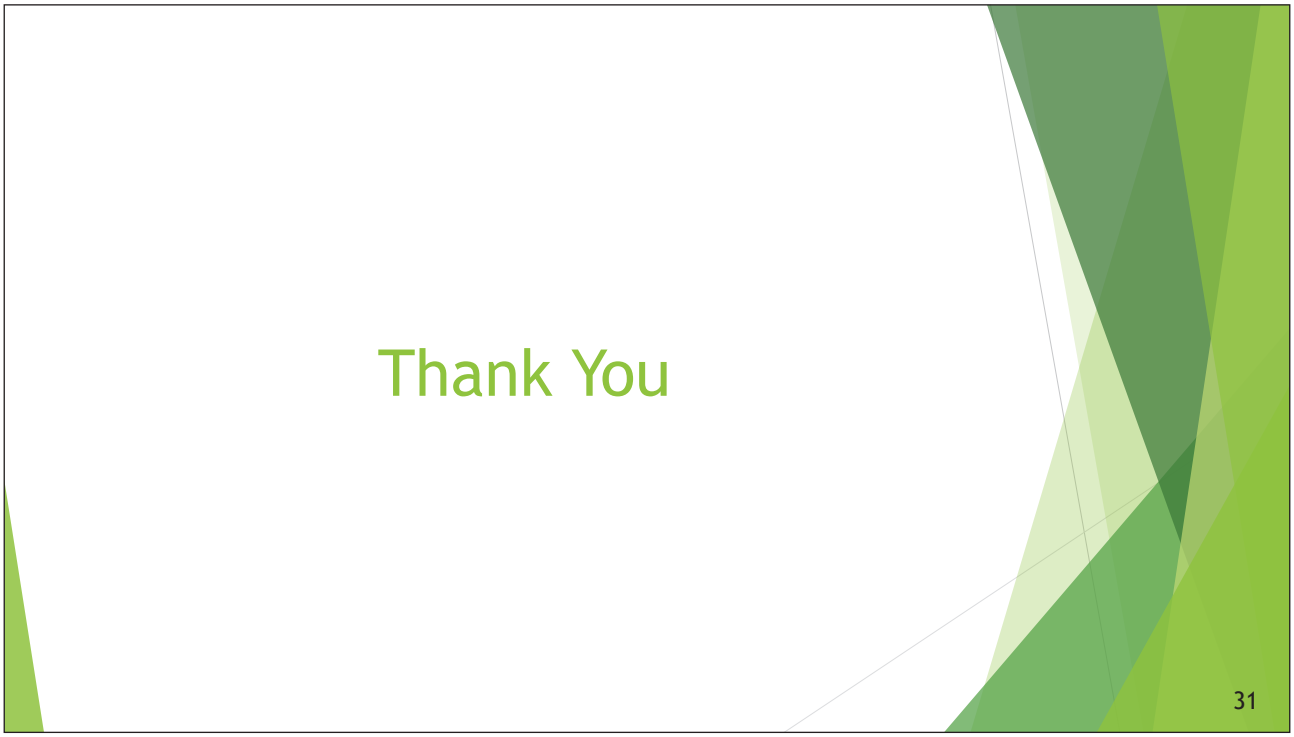
Thank You
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14-
REPAIR OF ANCILLARY MEMBERS AND FOUNDATION PROTECTION WORKS

1

CONTENTS

1. Expansion Joint Repairs
2. Bearing Repairs
3. Foundation Protection Works

2

1. Expansion Joint Repairs

Definition

- Expansion joints are usually provided to allow for thermal expansion and contraction of the bridge deck, and to allow for the movements due to traffic actions on the bridge.

  For expansion joint to function well, the following must be in place:

  - It must withstand loads and movements without causing any failure
  - It should be watertight
  - It should enable smooth transition of traffic from one deck to another
  - The joint's skid resistance should be equal to that of the adjacent surface
  - Easy to inspect and maintain.

3

3

1. Expansion Joint Repairs

1.1 Types of Expansion Joints

Rubber surface type

Steel tooth type

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1. Expansion Joint Repairs

1.1 Types of Expansion Joints

Steel finger type

Buried type

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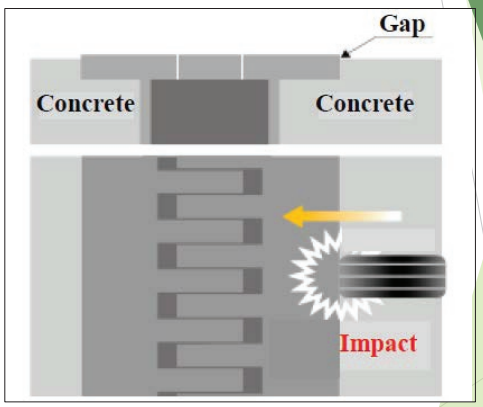
1. Expansion Joint Repairs

1.2 Common Defects on Expansion Joints

Cracks on post cast concrete



Unevenness (gap) between pavement and post cast concrete portion.

6

6

1. Expansion Joint Repairs

1.2 Common Defects on Expansion Joints cont…

Butt type:

- Deformation or broken steel angle line
- Missing steel angle line
- Cracking on the mortar

Buried type:

- Map cracking
- After increasing crack density, separation/delamination of the surface layer and pothole occurs.

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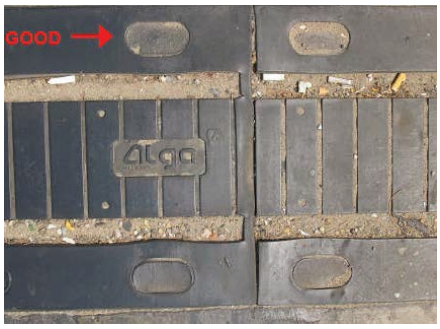
1. Expansion Joint Repairs

1.2 Common Defects on Expansion Joints cont…

Rubber faceplate type:

- Missing seal caps
- Loose or missing fixing nuts
- Damaged anchor bolts



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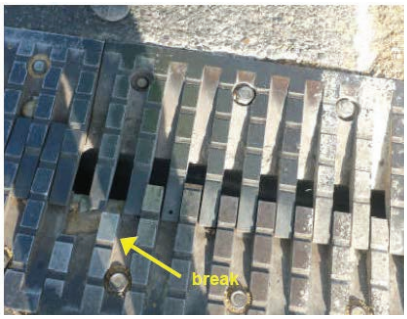
1. Expansion Joint Repairs

1.2 Common Defects on Expansion Joints cont…

Rubber faceplate type:
- Worn-out/damaged surface rubber



Steel faceplate type:
- Broken steel member

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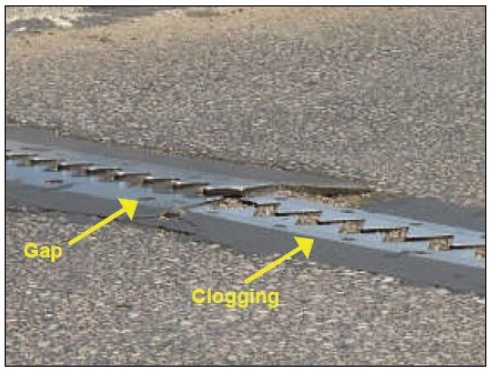
1. Expansion Joint Repairs

1.2 Common Defects on Expansion Joints cont…

Steel faceplate type:

- Gap on the faceplate
- Clogging of the expansion gap



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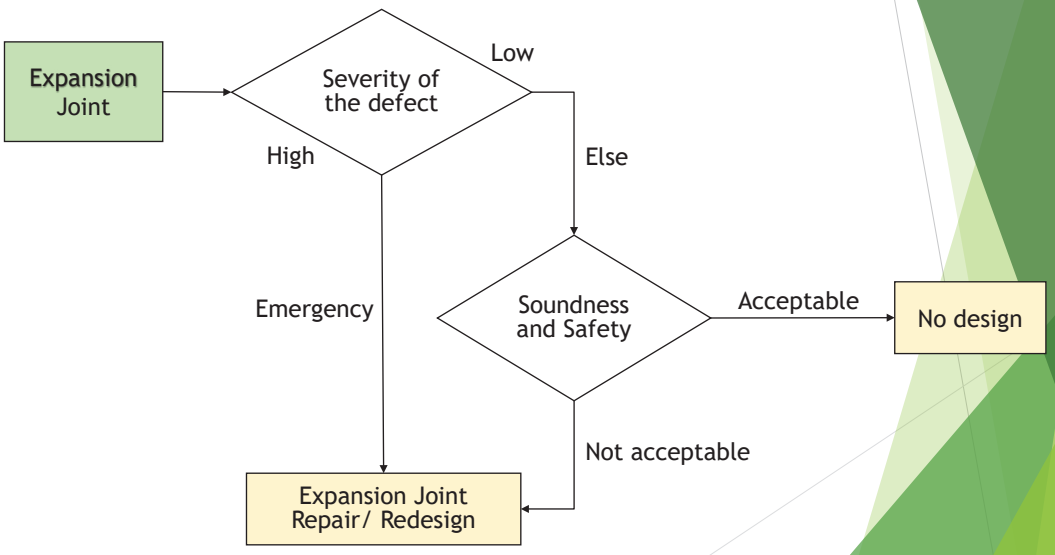
1. Expansion Joint Repairs

1.3 Selection of repair methods



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1. Expansion Joint Repairs

1.4 Expansion Joint Repair Methods

Deteriorated Member	Expansion gap	Conditions of deterioration	Repair Method	Remark
Expansion joint body	Allowable range	Locally	Partial Repair Method	Bolts & nuts, surface rubber, crack repair by welding. etc
		Entirely	Full replacement Method (Same Type)	
	Disallowable range		Full replacement Method (Different Type)	
Post-cast concrete		Cracking, Separating	Post-cast Concrete repair	

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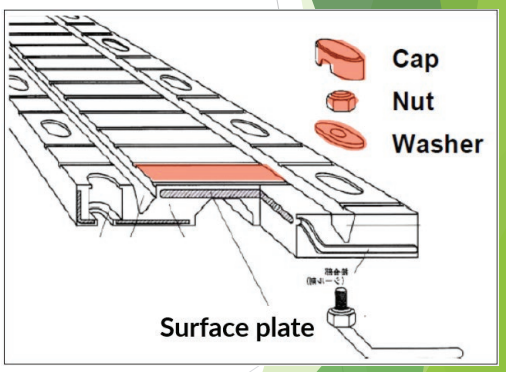
1. Expansion Joint Repairs

1.4 Expansion Joint Repair Methods

1.4.1 Partial repair method

- This method is suitable when the deterioration of an expansion joint is localized, and the deterioration can be remedied by changing damaged parts with new ones.
- Damaged surface plate, anchor bolts and any other parts to be replaced with new ones.



Note:

Replacement/repair of the anchor part/bolt needs removal of concrete which is costly and takes time.

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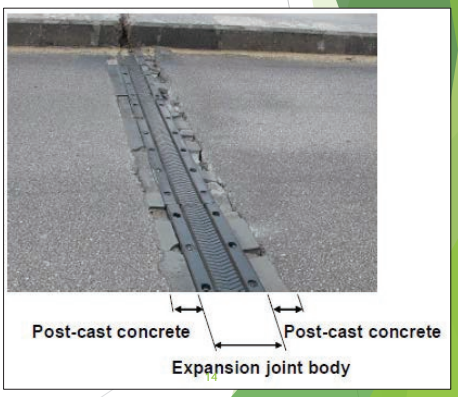
1. Expansion Joint Repairs

1.4 Expansion Joint Repair Methods

1.4.1 Partial repair method cont…

Post-cast concrete repair method

- The Post-cast concrete portion fixes an expansion joint body to the superstructure.
- When cracks and/or splitting is observed on the portion, the existing post-cast concrete portion is removed, loose concrete adherent to the anchoring rebar is blasted and concrete properly re-cast.



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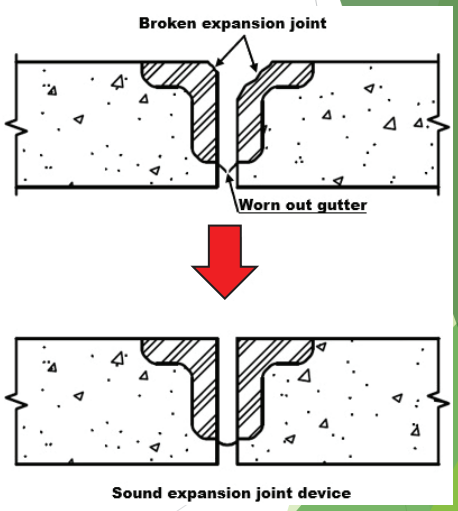
1. Expansion Joint Repairs

1.4 Expansion Joint Repair Methods cont…

1.4.2 Full replacement (Same type)

- When the deterioration of expansion joint by normal wear and tear cannot be repaired by the partial repair method, then the damaged expansion joint shall be fully replaced with the same structural type.



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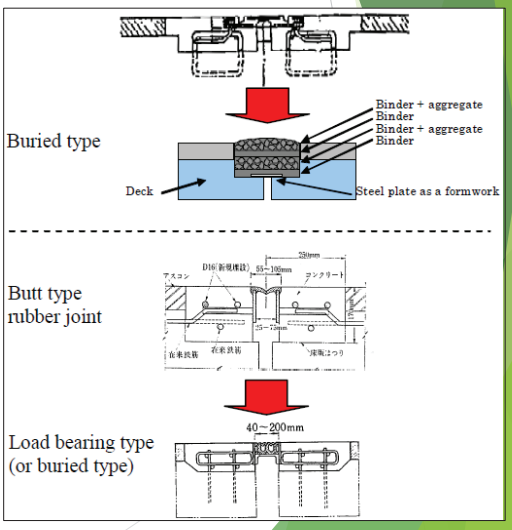
1. Expansion Joint Repairs

1.4 Expansion Joint Repair Methods cont…

1.4.3 Full replacement (different type)

- When the deterioration on an expansion joint is caused by inadequate design, capacity or other reasons, then the damaged expansion joint shall be fully replaced with a different structural type.



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2. Bearing Repairs

Definition

- A bearing is a component of a bridge that transmits loads received from the deck on to the substructure and to allow controlled movement due to temperature variations and thereby reduce the stresses involved.
- A bearing is found between the superstructure and the substructure.

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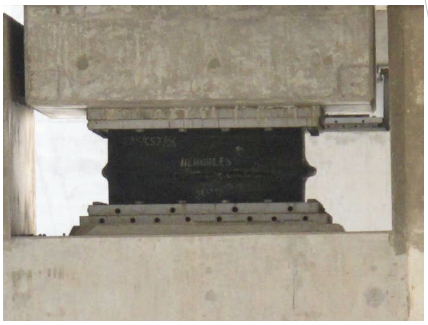
2. Bearing Repairs

2.2 Types of Bearings

Steel bearing



Rubber bearing (damaged)

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2. Bearing Repairs

2.3 Common Damages/ Defects on Bearings

- Broken mortar seat

- Exposed rebars in the concrete bearing seat

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2. Bearing Repairs

2.3 Common Damages/ Defects on Bearings

- Clogging/soil choking
- Reoccurrence of corrosion

- Depressing breakage
- Clogging/soil choking

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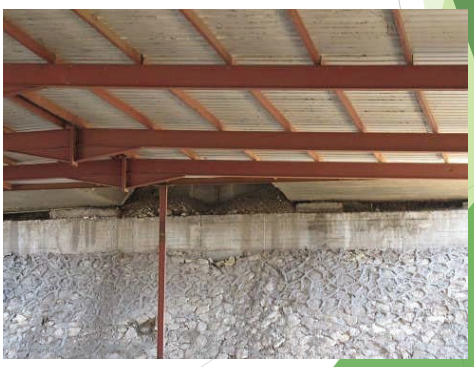
2. Bearing Repairs

2.3 Common Damages/ Defects on Bearings

- Carbonation of coating rubber due to fire accident



- Accumulation of sand
- Buried in sand

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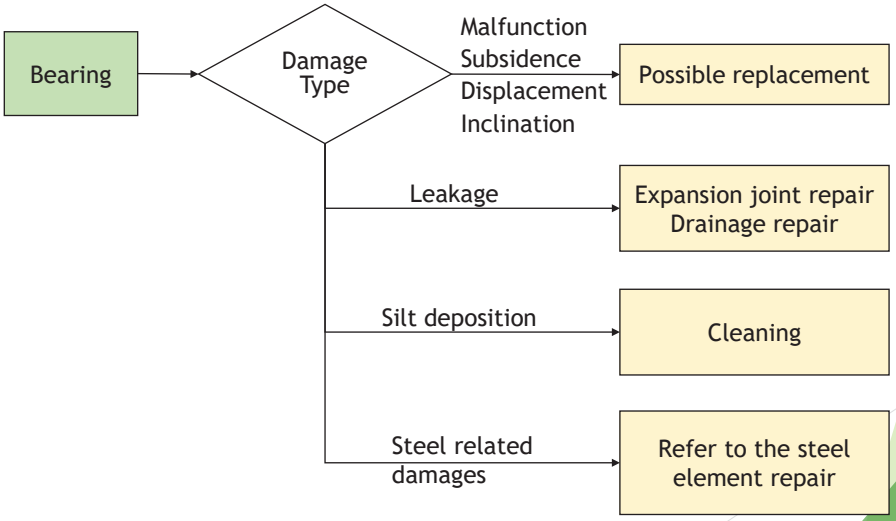
2. Bearing Repairs

2.4 Methods of bearing repair



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2. Bearing Repairs

2.4 Methods of bearing repair

Deteriorated Member	Range & Conditions of damage	Repair Method		Remark
Bridge Bearing Body	Entirely	Cause of damage does not arise from bridge bearing type	Full replacement Method (Same Type)	
		Cause of damage arise from bridge bearing type	Full replacement Method (Different Type)	
	Localised Damage of member	Roller, pin, bearing plate, anchor bolt, lock nut, side block etc	Partial Repair Method	
	Corrosion	Touch up paint Method		
Levelling Mortar	Cracking, Separating	Mortar Recasting Method		

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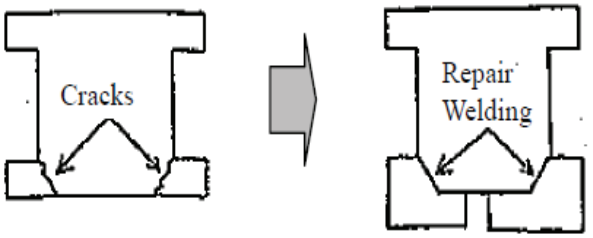
2. Bearing Repairs

2.4 Methods of bearing repair

2.4.1 Partial Repair Method

- When the damage of the bearing is localized and the part replacement or the part repair is available, then the partial repair method is selected.



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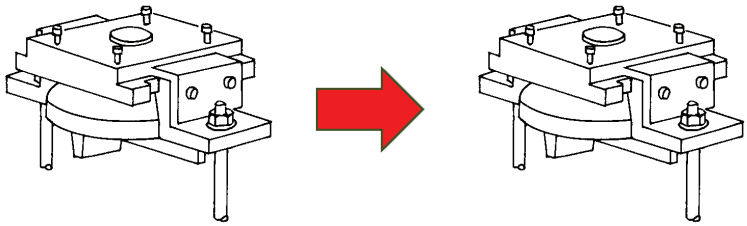
24

2. Bearing Repairs

2.4 Methods of bearing repair

2.4.2 Full replacement method (same type)

- When the damage of bearing is neither localized nor repairable and a structural type of current bearing is appropriate, the damaged bearing is replaced with same structural type bearing.



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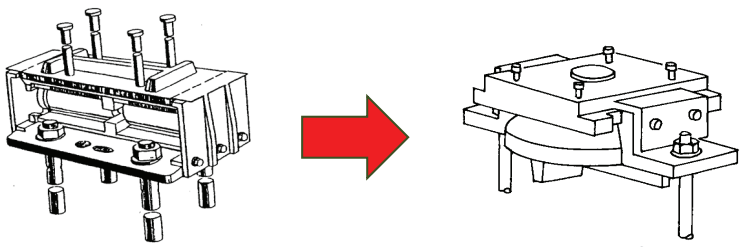
2. Bearing Repairs

2.4 Methods of bearing repair

2.4.3 Full Replacement Method (different type)

- This method is used when the damage of a bridge bearing extends entirely and the soundness cannot be restored by partial repair method.
- Moreover the causes of the damage can not be solved by replacing with the same structural bridge type bearing.



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2. Bearing Repairs

2.4 Methods of bearing repair

2.4.4 Paint repair method

- This method involves the removal of rust, surface preparation and application of paint.
- It is aimed at stopping corrosion from taking place

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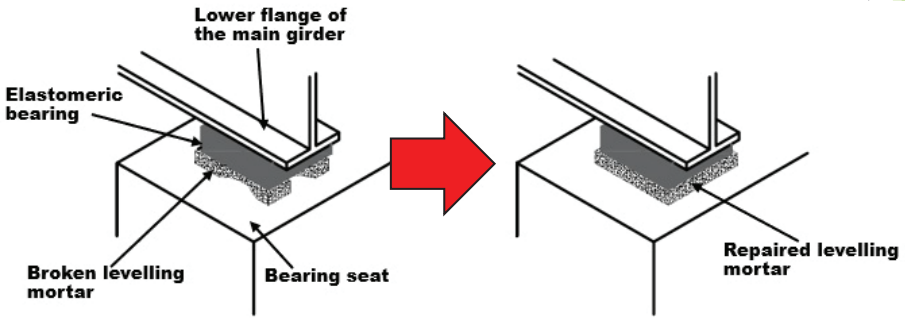
2. Bearing Repairs

2.4 Methods of bearing repair

2.4.5 Mortar recasting method

- After jacking the superstructure, remove the broken leveling mortar and reconstruct the leveling mortar with shrinkage compensation mortar.



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3. Foundation protection works

Definition & Classification

- Foundation is the lowest part of the substructure that is in direct contact with the soil which transfers loads to the soil safely
- Foundations are classified into two:
  i. Shallow foundations
     - Footings
  ii. Deep foundations
     - Pile foundation

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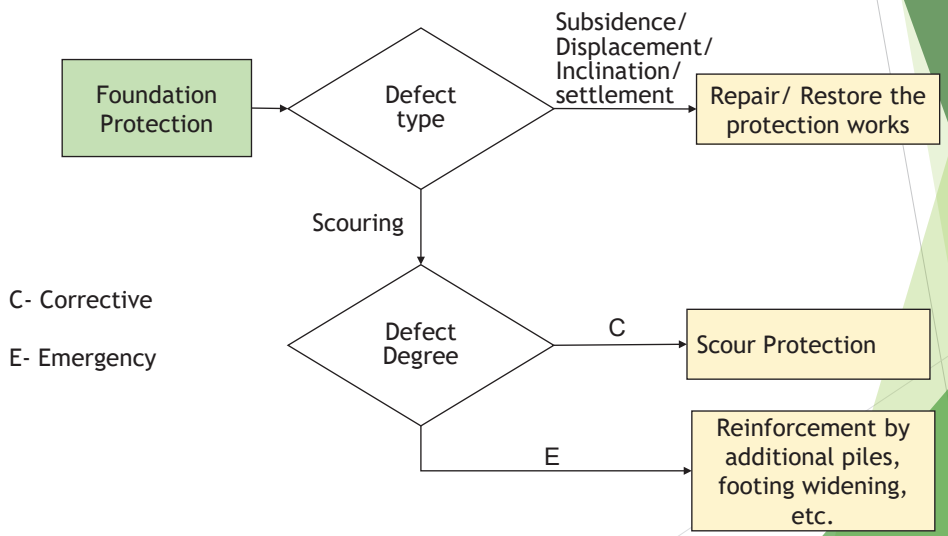
3. Foundation protection works

3.1 Repair of foundation protection works



30

3. Foundation protection works

3.2 Scouring

- Scouring is lowering or loss of top bed material around the bridge foundation.
- Scouring around bridge foundation is difficult to monitor and subsequent foundation failure due to scour is usually sudden.

Causes of Scouring

i. Turbulent river flow
ii. Weak riverbed materials
iii. Improper/inadequate foundation protection
iv. Human activities (Sand harvesting)

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3. Foundation protection works

3.2 Scouring cont…

Effects of Scouring

i. Loss of backfill material.
ii. Exposed piles.
iii. Settlement of the foundation
iv. Slope/foundation protection failure
v. Bridge instability

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3. Foundation protection works

3.2 Scouring cont…

Effects of Scouring cont…

Exposed pile foundation

Njiru bridge

Thwake bridge

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3. Foundation protection works

3.2 Scouring cont…

Pile protection works underway

Pile repair works ongoing at Thwake Bridge

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3. Foundation protection works

3.2 Scouring cont…

Pile protection works completed.

Thwake Bridge

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3. Foundation protection works

3.2 Scouring cont…

Mitigation Measures

i. Slope Protection with Foundation Supported by Piles
ii. Gabion Mattress
iii. Nylon Fibre Gabion
iv. Stone Pitching/ Revetment
v. Rockfill/riprap

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3. Foundation protection works

3.2 Scouring cont…

3.2.1 Mitigation Measures for scouring

a) Slope Protection with Foundation Supported by Piles

- Slope protection around the substructures is often damaged due to scouring, rapid river flow, improper construction, change in river course among others.
- In most of the defective cases, foundation for the slope protection was not provided leading to either sliding or scouring.
- Repair involves provision of appropriate foundation at its base.

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3. Foundation protection works

3.2 Scouring cont…

3.2.1 Mitigation Measures for scouring

a) Slope Protection with Foundation Supported by Piles cont…

- 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.

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3. Foundation protection works

3.2 Scouring cont…

3.2.1 Mitigation Measures for scouring

a) Slope Protection with Foundation Supported by Piles cont…

- 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.

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3. Foundation protection works

3.2 Scouring cont…

3.2.1 Mitigation Measures for scouring

b) Gabion Mattress

- Gabion mattresses are box units where the plan area is large compared to its height.
- Each unit is subdivided into compartments normally to give cells 2m x 1m in plan.
- Local scouring around the pier often occurs due to strong stream flow, weak riverbed materials and type of foundation.
- The worst damage that could occur due to scouring is the settlement of the bridge pier, eventually leading to undermining of the base and failure of the bridge.

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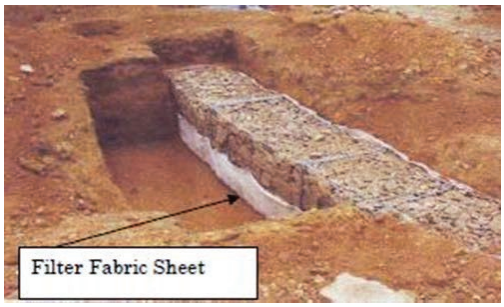
3. Foundation protection works

3.2 Scouring cont…

3.2.1 Mitigation Measures for scouring

b) Gabion Mattress

- Thus, protection against local scouring is intended to eliminate or minimize future damage to the bridge substructure.



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3. Foundation protection works

3.2 Scouring cont…

3.2.1 Mitigation Measures for scouring

c) Nylon Fibre Gabion

- Nylon Fibre Gabion is used for prevention of scour on pier foundation and other underwater structures.
- It consists of a bag body formed by knitted fabric made of nylon.
- The bag is filled with boulders or stones which are also used for conventional box-type zinc-coated wire gabions.
- The nylon 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.

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3. Foundation protection works

3.2 Scouring cont…

3.2.1 Mitigation Measures for scouring

c) Nylon Fibre Gabion cont…

- Boulders to be used shall conform to broken rock 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 m^3
- After installation of boulders, Nylon Fibre Gabion shall be transported to scoured area by mechanical means.
- Using backhoe lay gabions in scoured portion. Continue laying up to designated elevation.

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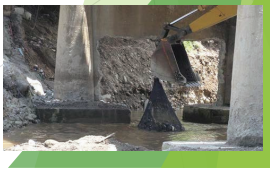
3. Foundation protection works

3.2 Scouring cont…

3.2.1 Mitigation Measures for scouring

c) Nylon Fibre Gabion cont…

Laying process



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References

- Information on repair of expansion joints, refer to Bridge Repair Manual chapter 3, pages 213-219.
- Information on repair of bearings, refer to Bridge Repair Manual chapter 3, pages 220-237.
- Information on foundation protection works, refer to Bridge Repair Manual chapter 3, pages 261-273.

15-
COST ESTIMATION
IN BRIDGE MAINTENANCE

1

CONTENTS

1. Introduction to Cost Estimation
2. Importance of Cost Estimation
3. Challenges Related to Cost Estimation
4. Role of Cost Estimation Administrator
5. Cost Configuration
6. SRUQ*1 and P/R*2
7. Cost Estimation Flow
8. PDCA Cycle for Cost Estimation

*1 SRUQ: Standard Resource Usage per (Unit) Quantity
*2 P/R: Productivity Rate (P/R)

2

1. Introduction to cost estimation

- Cost Estimation involves building up an approximate cost of a project forecasting on the resources needed to complete a project within a defined scope, quality and time.
- Various materials, equipment and labor are used during construction and maintenance of structures.

3

2. Importance of cost estimation

- Road Agencies and contractors are key in the establishment of optimum cost of projects in the light of scarce resources available for construction and maintenance of bridges.
- Road agencies must be accountable to the government as well as the public and road users for effective utilization of the available road maintenance fund.
- The objectives include:
  - To use the Road Maintenance Fund in the contract effectively and efficiently.
  - To use the proper standards and manuals of cost estimation.
  - To clarify the basis of the estimated unit prices and quantities.

4

2. Importance of cost estimation

Budgeting

- To evaluate the appropriate investment amount by calculating the predetermined cost of the works for adequate planning.
- To calculate the cost of proposed works so that contractors can deliver quality work and make reasonable profit within stipulated schedule.
- To calculate with accuracy the cost estimates related to indirect work cost, overheads and profits of miscellaneous bridge items including:
  - Project service road, scaffolding, support/timbering, detour rivers, waterways and road, traffic regulation, temporary enclosure, temporary sidewalk, material storage, etc., that are not part of the final products.

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3. Challenges and solutions in Cost Estimation

3.1 Challenges

- Variation of prices of construction materials and labor
- Inadequate scoping and scope creep
- Technological, social and political changes
- Change in government policies and regulation
- Cost overruns due to;
  - Unforeseen physical obstructions
  - Inflation
  - Force majeure

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3. Challenges and solutions in Cost Estimation

3.2 Solutions

- Allow for contingencies
- Allow for an item on variation of prices in the computation of the cost of the project.
- Adequate scoping and proper public participation
- Allow for continuous capacity building
- Invest in new technology and
- Aligning to policies as per the government priorities.
- Monitoring and evaluation of project cost
- Undertake feasibility studies prior to cost estimation.

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4. Responsibility of the Ministries, Departments and Agencies (MDAs) and County Governments

- Justification of the anticipated project cost by performing a cost estimation based on a standardized method.
- Apply professional and engineering judgment in quantification of maintenance and repair works during the project cycle.
- Ensure value for money.

8

5. Roles of Cost Estimation Administrator

The roles of a cost estimation administrator are as follows:

- Conducting surveys on costs, establishing standard costs and updating the costs annually.
- Conducting surveys on productivity, establishing productivity indices and updating the productivity indices.
- Management and updating of the Cost Estimation Manual.

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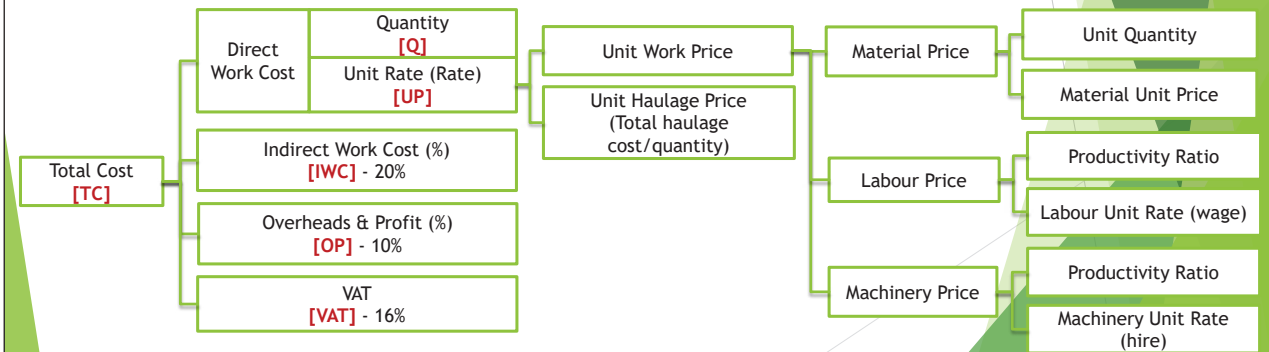
6. Cost Configuration

6.1 Principal Structure of Cost Estimation

- Road works consist of various work items that are aggregated into a work package. The total cost of any work package is structured in the formula:

$$TC = \Sigma (Q \times UP) \times (1 + IWC) \times (1 + OP) \times (1 + VAT)$$



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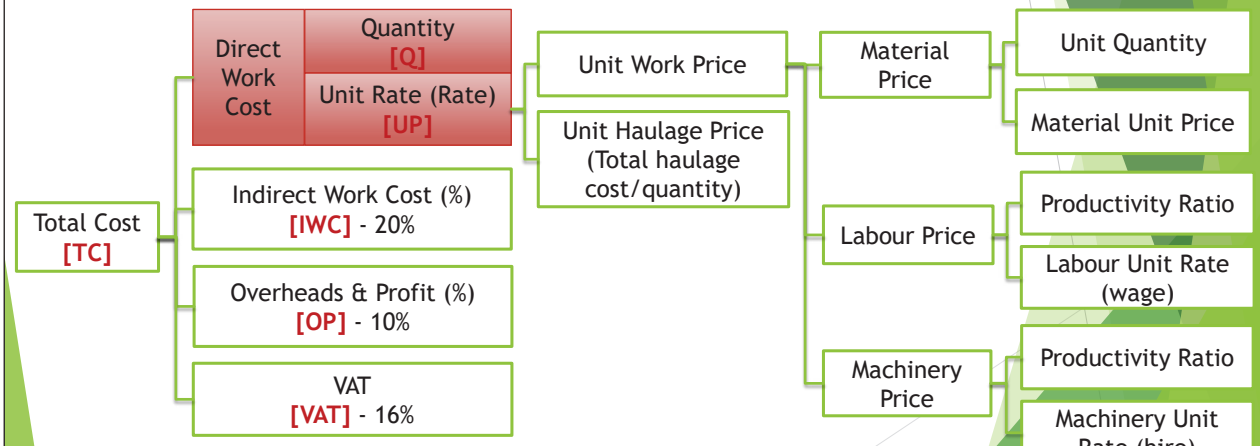
6. Cost Configuration

6.2 Direct work cost

- $TC = \Sigma (Q \times UP) \times (1 + IWC) \times (1 + OP) \times (1 + VAT)$



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6. Cost Configuration

6.2 Direct work cost

- Direct work cost is the accumulation of all input costs for the execution of each work item.
- This is a product of quantity and its Unit Rate.
  - The combination of the unit work price (a pure work price assuming that all the resources are on site) inclusive of the haulage cost constitute the Unit Rate.

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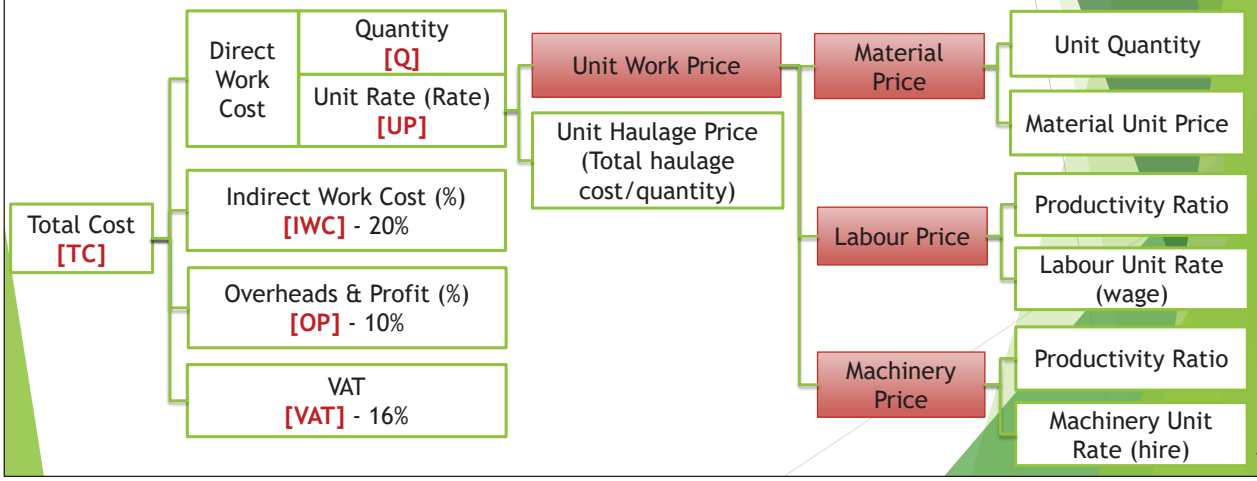
6. Cost Configuration

6.2 Direct work cost

6.2.1 Unit Work Price

$$TC = \Sigma (Q \times UP) \times (1 + IWC) \times (1 + OP) \times (1 + VAT)$$



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6. Cost Configuration

6.2 Direct work cost

6.2.1 Unit Work Price cont…

- The Unit Work Price consists of the Material, Labour and Machinery Unit Rate.
- The material, labour and machinery Rates used for cost estimation by procuring entities are basically derived from the official price indices given by the government entities.
- They are open to the public and based on the nation-wide market surveys, they can be assumed to be the average prices in Kenya.
  - Material Price: Material Price List from Kenya National Bureau of Statistics (KNBS)
  - Labour Price: The Regulation of Wages (General) (Amendment) Order, The Labour Institution Act and The Ministry in charge of Labour.
  - Machinery Price; Equipment Hire Rate List from Mechanical and Transport Division and The Ministry in charge of Roads.

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6. Cost Configuration

6.2 Direct work cost

6.2.1 Unit Work Price cont…

- Labour price is provided in the recently updated Cost Estimation Manual.
- Material and Machinery prices vary across the country.
- The recommended prices are revised periodically. The prices may be updated in an ad-hoc basis when substantial changes take place during the fiscal year (e.g. case of high inflation or embargo).
- When some material and machinery prices are not covered in the recommended price indices, the average market prices acquired from the survey by the cost estimate administrator or provisional prices by referring to similar items are used. Those prices should be revised immediately once the recommended prices are available.

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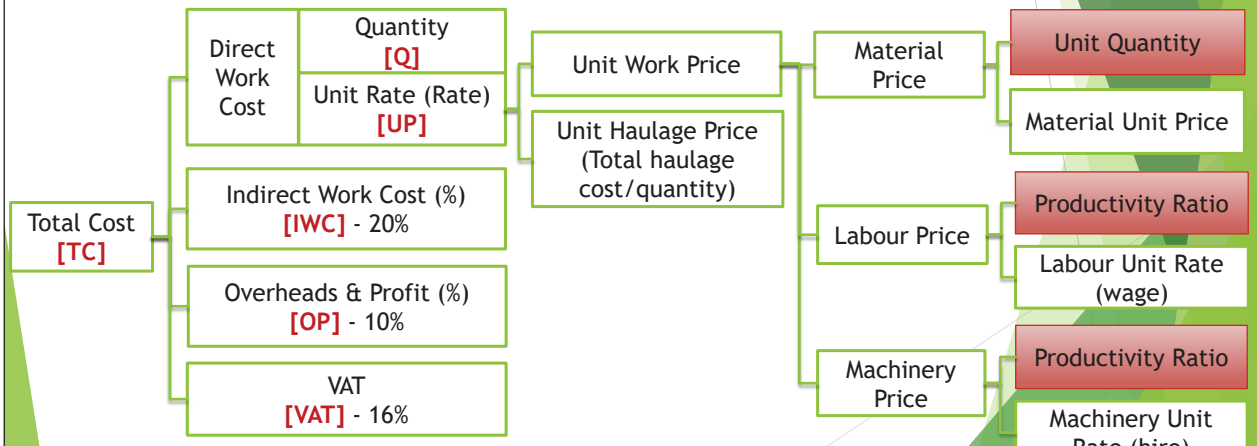
6. Cost Configuration

6.2 Direct work cost

6.2.2 Unit quantity and productivity

- $TC = \Sigma (Q \times UP) \times (1 + IWC) \times (1 + OP) \times (1 + VAT)$



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6. Cost Configuration

6.2 Direct work cost

6.2.2 Unit quantity and productivity cont…

- Unit quantity of material (the amount of material used per unit of work), labour productivity (the number of people required per unit of work), and machinery productivity (the number of hours/days of machinery operation needed per unit of work) are determined with the following references:
  - Standard Specification for Road and Bridge Construction.
  - Standard drawings.
  - Average productivity rates from site surveys and site experiences.

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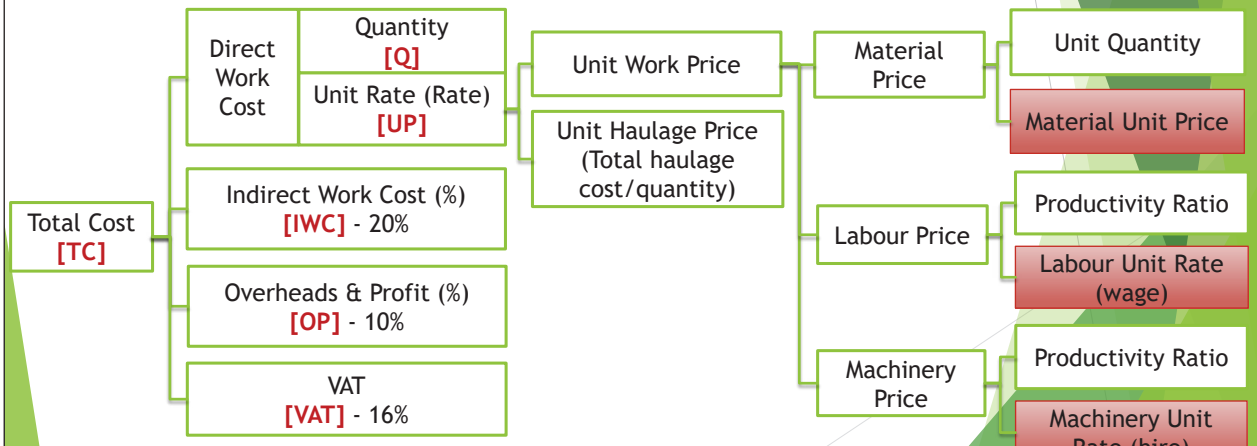
6. Cost Configuration

6.2 Direct work cost

6.2.3 Unit Price and Unit Rate

- $TC = \Sigma (Q \times UP) \times (1 + IWC) \times (1 + OP) \times (1 + VAT)$



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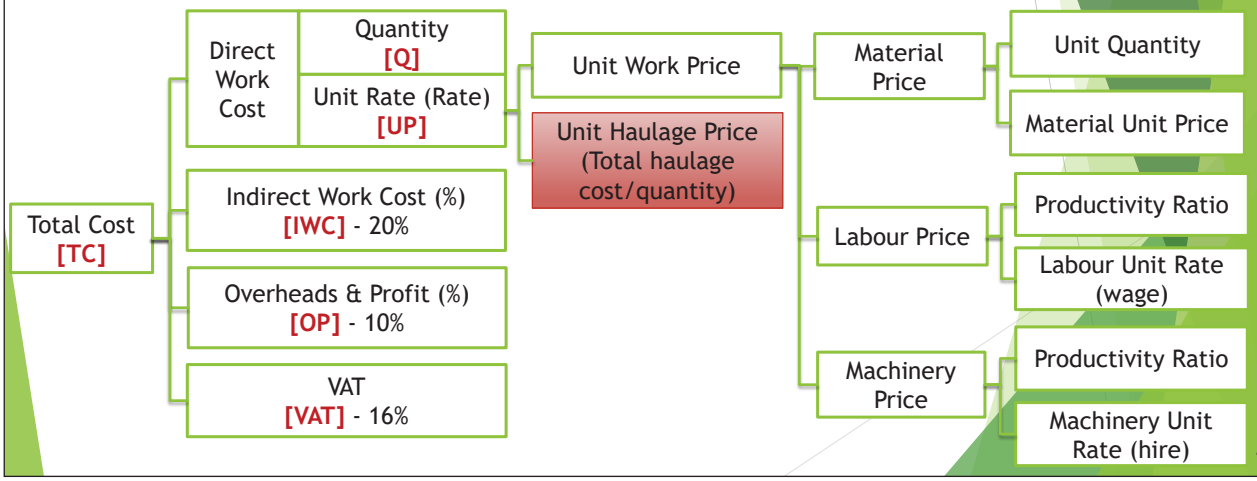
6. Cost Configuration

6.2 Direct work cost

6.2.4 Haulage cost

- $TC = \Sigma (Q \times UP) \times (1 + IWC) \times (1 + OP) \times (1 + VAT)$



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6. Cost Configuration

6.2 Direct work cost

6.2.4 Haulage cost cont…

- Site location is a major parameter to determine the Unit Rate so that the haulage cost to transport material or equipment should be carefully estimated.
- The calculated total haulage cost is divided by the given quantity of the work item and then added to the unit work price to get a Unit Rate of the work.
- If a different unit rate for haulage is available, it may be used regardless of the aforementioned equation.

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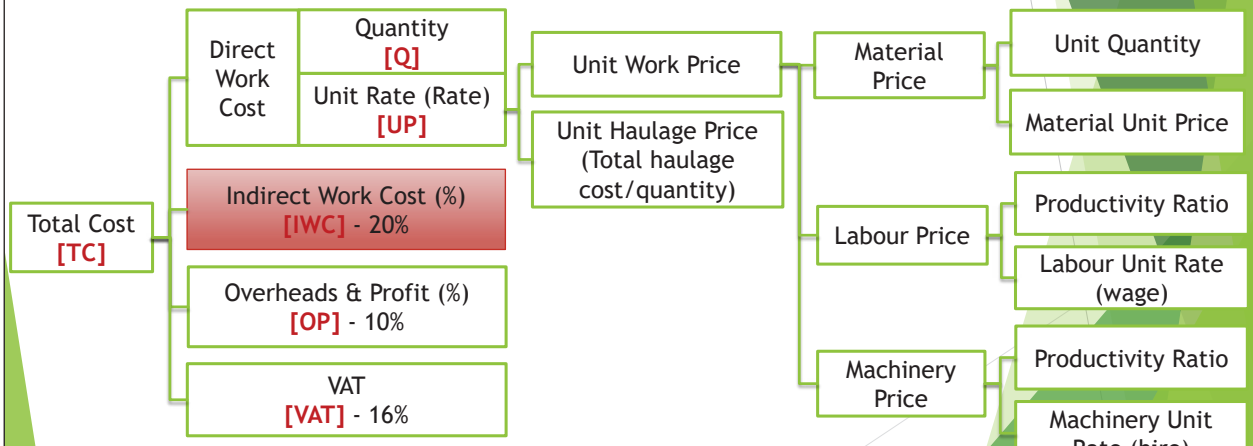
6. Cost Configuration

6.3 Indirect work cost

- $TC = \Sigma (Q \times UP) \times (1 + IWC) \times (1 + OP) \times (1 + VAT)$



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6. Cost Configuration

6.3 Indirect work cost

- Indirect Work Cost are the costs related to management and administration. It is expressed as a percentage of Direct Work Cost.
- Indirect work costs include the following items;
  - Human Resource Management costs (e.g. recruiting, staff welfare, transportation, insurance, PPEs, etc.)
  - Site staff allowances.
  - Management costs (e.g. site office maintenance, office equipment, communication, transportation, etc.)
  - Safety measures.
  - Social charges (e.g. Local taxes and public charges, welfare, etc.)

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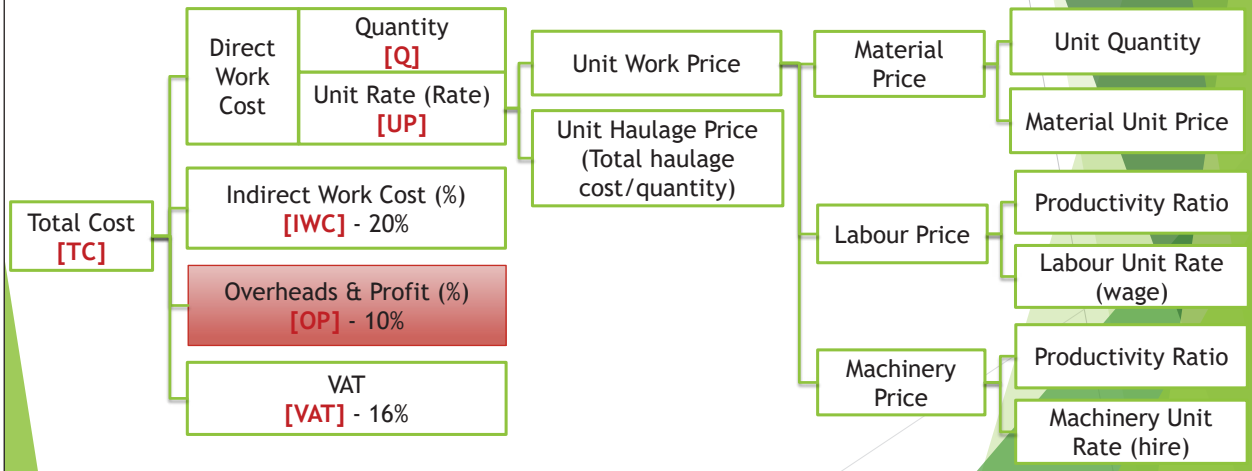
6. Cost Configuration

6.4 Overheads and profits

- $TC = \Sigma (Q \times UP) \times (1 + IWC) \times (1 + OP) \times (1 + VAT)$



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6. Cost Configuration

6.4 Overheads and profits

- Overheads and profits are expressed as a percentage of the sum of Direct and Indirect Work Costs. Overheads and Profit include the following items;
  - Head office staff salaries and allowances.
  - Head office management costs (e.g. office maintenance, office equipment, communication, transportation, etc.)
  - Corporate Social charges (e.g. insurance, tax and public charges, welfare, etc.)
  - Research and Development.
  - Advertisement and publicity.
  - Depreciation costs of fixed assets.
  - Profit margin (bonuses, dividends to shareholders, internal reserves, etc.)

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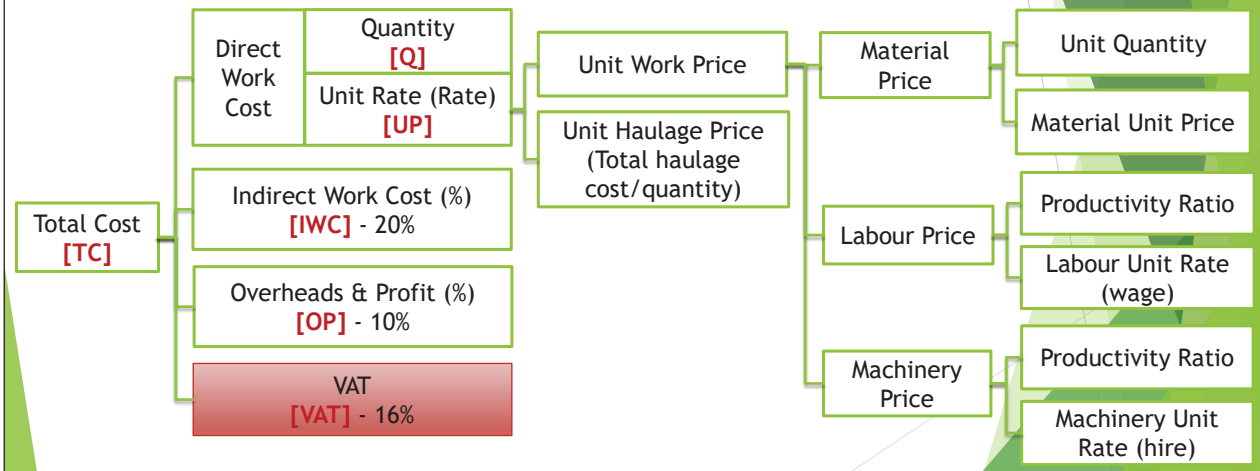
6. Cost Configuration

6.5 VAT

- $TC = \Sigma (Q \times UP) \times (1 + IWC) \times (1 + OP) \times (1 + VAT)$



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6. Cost Configuration

6.5 VAT

- Value-added tax (VAT) is a percentage determined by taxation regulations.

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6. Cost Configuration

Sample calculation

- Estimate the Direct Cost, Indirect Cost, Overheads and Profit, VAT Cost and Total Project Cost for mixing one (1) cubic meter of C25 concrete. Calculate to 2 decimal places.

Given the following cost of labour and materials:

Name	Unit	Unit price (Ksh)
Skilled Labour: Overseer	Person Day	1,800
Artisans G2	Person Day	1,384
Unskilled labour	Person Day	672
Support Staff	Person Day	750
Cement (Ordinary Portland)	Kg	15
Fine aggregates(Sand)	m^3	2,160
Graded aggregates (Ballast)	m^3	1,600

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B5 Concrete mix work
Unit m^3
Quantity 1

Code	Name	Type	Unit	Unit price(KSh)	Quantity	Sum (KSh)	Remarks
22.50.007	Skilled Labour: Overseer		Person Day		0.75		Based on average estimated productivity in Japan (see note)
22.50.005	Artisans G2		Person Day		2.38		Based on average estimated productivity in Japan (see note)
22.50.002	Unskilled labour		Person Day		0.62		Based on average estimated productivity in Japan (see note)
22.50.001	Support Staff		Person Day		0		
22.70.004	Cement (ordinary portland)		Kg		0.42		365*1.1 (loss margin) = 401.5
22.69.009	Fine aggregates(sand)		m^3		0.42		0.38*1.1 (loss margin) = 0.418
22.70.002	Graded aggregates (ballast)		m^3		0.84		0.76*1.1 (loss margin) = 0.836
	Subtotal						
	Miscellaneous Cost		%		0		% of subtotal
	Total						
	Per unit						Total/Quantity

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6. Cost Configuration

Sample calculation

Direct Cost	13,341.76	Kshs.
Indirect Cost	1,334.18	Kshs.
Overheads and Profit	2,935.19	Kshs.
Sub Total	17,611.12	Kshs.
Add VAT	2,817.78	Kshs.
Total Project Cost	20,428.90	Kshs.

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B5 Concrete mix work
Unit m^3
Quantity 1

Code	Name	Type	Unit	Unit price (KSh)	Quantity	Sum (Ksh)	Remarks
22.50.007	Skilled Labour: Overseer		Person Day	1,800	0.75	1,350.00	Based on average estimated productivity in Japan (see note)
22.50.005	Artisans G2		Person Day	1,384	2.38	3,293.92	Based on average estimated productivity in Japan (see note)
22.50.002	Unskilled labour		Person Day	672	0.62	416.64	Based on average estimated productivity in Japan (see note)
22.50.001	Support Staff		Person Day	750	0	-	
22.70.004	Cement (ordinary portland)		Kg	15	0.42	6,030.00	365*1.1 (loss margin) = 401.5
22.69.009	Fine aggregates(sand)		m^3	2,160	0.42	907.20	0.38*1.1 (loss margin) = 0.418
22.70.002	Graded aggregates (ballast)		m^3	1,600	0.84	1,344.00	0.76*1.1 (loss margin) = 0.836
	Subtotal					13,341.76	
	Miscellaneous Cost		%		0	-	% of subtotal
	Total					13,341.76	
	Per unit					13,341.76	Total/Quantity

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7. SRUQ and P/R

7.1 SRUQ – Standard Resource Usage per (Unit) Quantity

- Standard Resource Usage per (Unit) Quantity (SRUQ) & Productivity Rate (P/R) are important parameters required for cost estimation.
- SRUQ is the volume of work input i.e. labour, materials and machines required to complete a unit work output.
  - For labour input, it is the ratio of the number of person-days to the volume of work completed.
  - For machines/ equipment, it is the ratio of the number of machine-days to the volume of work completed.
  - For materials, it is the ratio of the quantity of materials used to the volume of work completed.

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7. SRUQ and P/R

7.2 P/R – Productivity Rate

- Productivity Rate (P/R) is the inverse of SRUQ and it refers to the quantity of work output that can be completed by a unit input.

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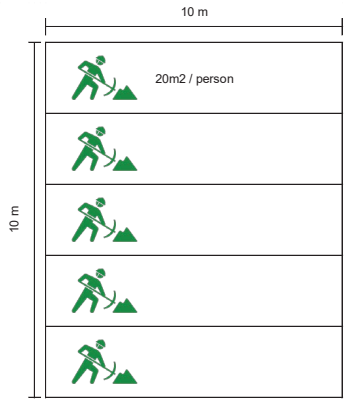
7. SRUQ and P/R

7.3 Example of Road Construction Work of labor based works



- Road Construction Work of 100m^2 is completed in 5 Person-Days.
- That is 5 persons each completing 20m^2 on a given day.
  - SRUQ = 5 person-days/ 100 m^2 = 0.05 Person-Days/m^2
  - Productivity Rate (P/R) = 20 m^2/Person-Day
  - SRUQ = 5 Person-Day / 100 m^2
  - P/R = 20 m^2 / Person-Day

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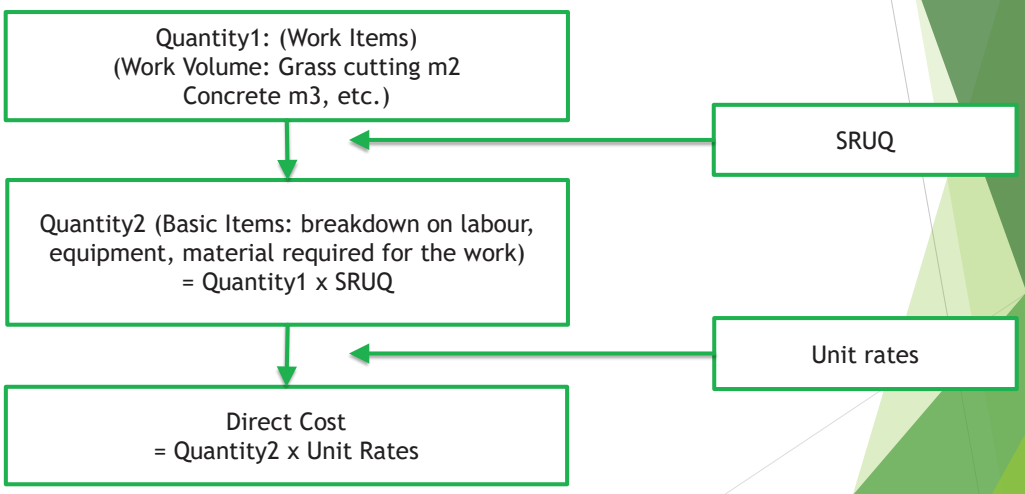
7. SRUQ and P/R

7.4 Concept of SRUQ and P/R



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7. SRUQ and P/R

7.5 Sample of Work Items / Quantity1

Work Items	Scope of Work	Unit	Quantity 1	P/R		Quantity 2 (Labour, Materials etc)
Excavation	Excavation, Hauling	m3	Excavation volume	SRUQl	Person Day	Labour
				SRUQm	m3, ton, etc	Material
				SRUQe	hours	Equipment/ Expenses
Concrete	Materials, Scaling, Weighing, Mixing	m3	Cast volume	SRUQl	Person Day	Labour
				SRUQm	m3, ton, etc	Material
				SRUQe	hours	Equipment/ Expenses

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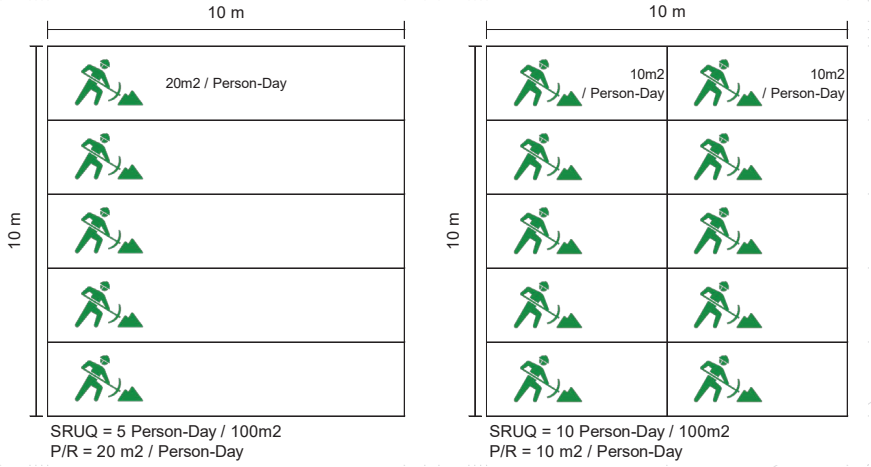
7. SRUQ and P/R

7.6 Illustration of SRUQ and Calculation of the required number of labourers.



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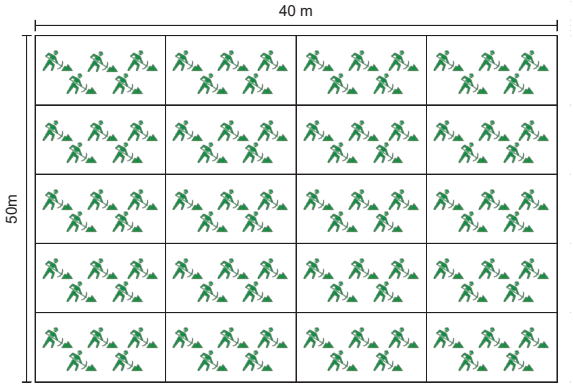
7. SRUQ and P/R

7.7 Calculation of the number of laborers from SRUQ

(SRUQ = 5 person day/100m^2)

SRUQ x Area = Number of Labors

5 Person Day/100m^2 x (50 x 40) = 100 Person Day



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8. Cost Estimation procedure

8.1 Flow of Cost Estimation Method (First Stage)

1. Cost Estimation Parameters
Project Condition
- Initial Mobilization Period, wet and dry periods in the months

Types of Quantities for Direct Cost
- Simple Quantity
- Actual Quantity

Unit Rates for machineries, materials and labour
SRUQs for machineries and labour

Unit Rates
Unit Rate of machineries, materials, supervisors, foremen, labourers, fuel, etc.,
Labour Productivity: SRUQs
Machinery Productivity: SRUQs

↓

2. Cost Estimation of Direct Cost
2.1 Maintenance Works
2.2 Haulage Cost
2.3 Miscellaneous Cost On the Carriageway Works
- Miscellaneous Cost On the Labour Based Works

2.4 Instructed Works

↓

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8. Cost Estimation procedure

8.2 Flow of the Cost Estimation Method (Second Stage)

3. Cost Estimation of the Indirect Cost/Overhead & Profit
3.1 Indirect Cost
3.2 Overhead & Profit

4. Cost Estimation of VAT

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9. PDCA Cycle for Cost Estimation

9.1 Plan-Do-Check-Action Cycle for Cost Estimation

- Scientific cost estimation is based on data collected from the actual road and bridge maintenance projects.
- The Cost Estimation Manual should therefore be revised periodically so that the data used is always up to date.
- Hence, the PDCA (Plan-Do-Check-Action) project cycle is introduced to express this periodic updating process.
- This process helps to improve the quality of the Cost Estimation Manual through progressive updating of the basic data.

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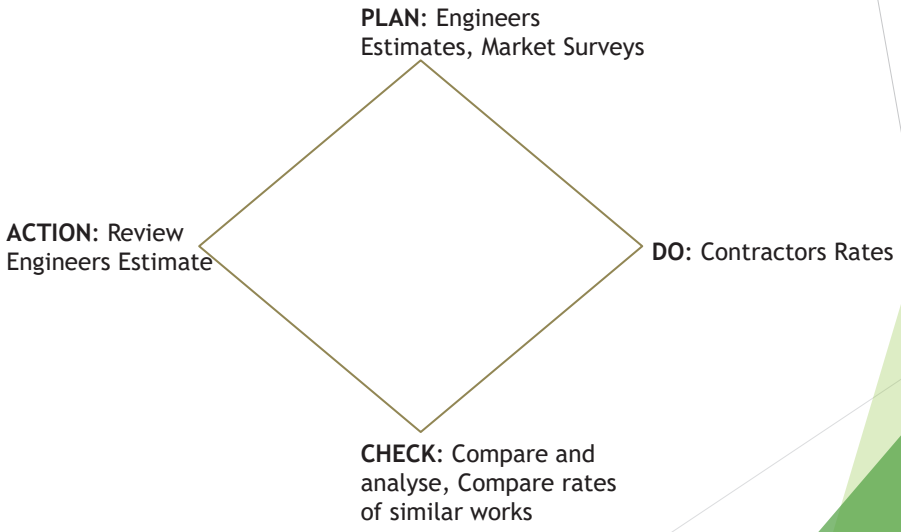
9. PDCA Cycle for Cost Estimation

9.1 Plan-Do-Check-Action Cycle for Cost Estimation



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9. PDCA Cycle for Cost Estimation

9.2 PDCA Cycle for Cost Estimation Related Activities

Item	Contents				Recommended	Action
Manual Utilization	P (Plan)	Planning the budget for next year projects			Every Year	Road Agencies
	D (Do)	Cost Estimation for the project				
Manual Revision	C (Check)	Cost Survey	Unit Rates Survey Indirect Cost and Overhead & Profit Survey	(Coordination and Referral with KNBS index, etc.)	Every 2 Years	KRB/CEU
				SRUQ (by work item)		
				SRUQ (by Road Agency)		
	A (Action)	Manual Update				

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10. Bridge Repair Work (35 items)

10.1 Scope of Routine Maintenance and Repair Method

Code	Item	Description of Repair Method
10200	Cleaning	  
	Unit: m^2 Measurement shall be in square metres of surfaces cleaned and approved.	
10300	Touch-up Painting	 
	Unit: m^2 This work will be measured for payment by the actual area in square meters of steel surfaces cleaned, painted and approved.	

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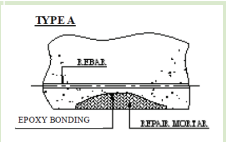
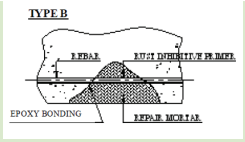
10. Bridge Repair Work (35 items)

10.1 Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
10400	Epoxy Coating on the Crack	 
	Unit: m^2 Measurement shall be in square meters of the cracks where epoxy coating is applied, as determined and approved by the Engineer.	
10500	Patching/ sectional repair	   
	Unit: m^2 or m^3 Measurement shall be square meter for depth less than 50mm calculated as the area instructed by the Engineer or shall be measured by the cubic meter for depth beyond 50mm calculated as the volume, or as instructed by the Engineer.	

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10. Bridge Repair Work (35 items)

10.1 Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
10600	Removal of obstructions from structures openings	
	Unit: LS Measurement shall be lump sum for sites described and approved by the Engineer.	
10700	Partial Replacement of Stone Masonry	
	Unit: m^2 Measurement shall be based on square meters.	

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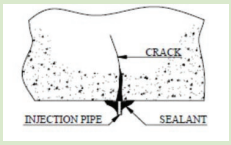
10. Bridge Repair Work (35 items)

10.1 Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
10800	Partial Replacement of Gabion Wire Mesh and Stone	 
	Unit: m^2 and m^3 Measurement shall be based on square meters for the gabion mesh and cubic metres for the stones.	
10900	Epoxy Injection	  
	Unit: m Measurement shall be in linear metre (m).	

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10. Bridge Repair Work (35 items)

10.1 Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
11000	Patching / Plastering	
	Unit: m^2 or m^3 Measurement shall be square meter for depth less than 50mm calculated as the area instructed by the Engineer or shall be measured by the cubic meter for depth beyond 50mm calculated as the volume, or as instructed by the Engineer.	
11100	Caulking	
	Unit: m Measurement shall be in linear meters (m).	

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10. Bridge Repair Work (35 items)

10.1 Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
11200	Carbon Fiber Sheet Bonding to Deck Slab	
	Unit: m^2 Measurement shall be in square metres.	
11300	Steel Plate Bonding	
	Unit: m^2 Measurement shall be in square metres.	

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10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
11400	Partial Deck Slab Replacement	   
	Unit: m^3, Tons and m^2 Measurement shall be based on cubic metres (m^3) for replaced concrete on the deck, rebars will be measured in tonnes (Tons) and formwork shall be measured in square metres (m^2).	
11500	Waterproofing on Deck Slab	 
	Unit: m^2 Measurement shall be in square meters.	

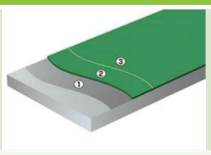
10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
11600	Fast Setting Mortar for Continued Deck Slab	  
	Unit: m^3 Measurement shall be in cubic meter.	
11700	Protective Mortar	 
	Unit: m^2 Measurement shall be area in square metres	

10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
11800	Protective Coating	 
	Unit: m^2 Measurement shall be in square meters.	
11900	Recasting Concrete / Grout	  
	Unit: m^3, Tons and m^2 Measurement shall be based on cubic metres (m^3) for concrete, rebars will be measured in tonnes (Tons) and formwork shall be measured in square metres (m^2).	

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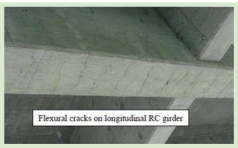
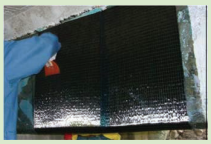
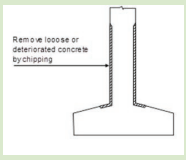
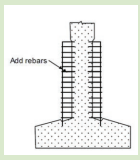
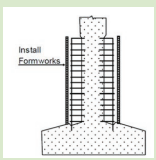
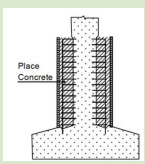
10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
12000	Carbon Fiber Sheet / Plate Bonding to Concrete Girder	  
	Unit: m^2 Measurements shall be in square metres.	
12100	Jacketing with Concrete	    
	Unit: m^3, Tons and m^2 Measurements shall be in tonnes of steel, cubic meters of concrete and square meters of formwork used.	

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10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
12200	Repainting	   
	Unit: m^2 Measurement shall be in square metres.	
12300	Steel Plate Adding	  
	Unit: Tons Measurement shall be in tonnes.	

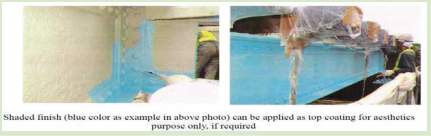
10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
12400	Carbon Fiber Plate Bonding	   
	Unit: m Measurement shall be in linear meters.	
12500	Tightening / Retightening of High-Tension Bolt	 
	Unit: No. Measurements shall be in numbers of bolts.	

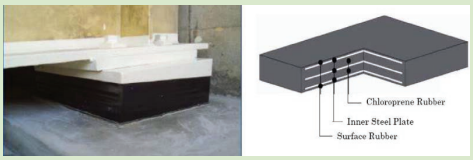
10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
12600	Anti-Corrosion Paint	 
	Unit: m^2 Measurement shall be by square meters.	
12700	Asphaltic Plug Joint	
	Unit: m Measurement shall be in linear meters.	

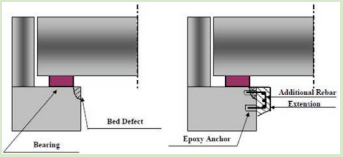
10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
12800	Replacement of Expansion Joint	
	Unit: m Measurement shall be in linear meters.	
12900	Replacement of Bearing	
	Unit: No. Measurement shall be in number of bearings replaced.	

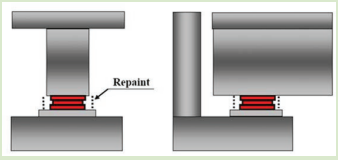
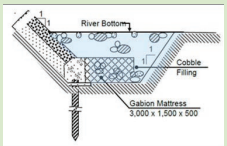
10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
13000	Extension of Bearing Seat	
	Unit: m^3 Measurement shall be in cubic meters.	
13100	Jack up Girder	  
	Unit: LS Measurement shall be in lumpsum for the length of the span jacked.	

10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
13200	Repainting of Steel Bearing	
	Unit: m^2 Measurement shall be in square meters.	
13300	Slope Protection with Foundation Supported by Piles	 
	Unit: LS Measurements shall be based on lumpsum amount.	

10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
13400	Gabions	
	Unit: Cubic meters m^3	
13500	Slope Patching	
	Unit: Cubic meters (m^3). For removal of damaged masonry. Cubic meters (m^3) for gravel fill and compaction. Square meters (m^2) for Stone masonry patching.	

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10. Bridge Repair Work (35 items)

Scope of Routine Maintenance and Repair Method cont…

Code	Item	Description of Repair Method
13600	Nylon Fiber Gabion	  
	Unit: m^3 Measurements shall be in cubic meters.	

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11. Units of measurement and payment

- Based on the nature of various requirements, Bridge Repair Works are a combination of the following works and services.

Bridge Repair Work	Bill of Quantities	Payment
Rehabilitation Works - To restore the Bridge and its approaches to the pre-defined standards	Prepared by the client	Unit rate payment determined by the contractor
Improvement Works - To Add New Characteristics to the Road and Bridge		
Emergency Works - To Reinstate the Road after Damage has occurred as a result of natural occurrences with unexpected consequences under the condition defined in the contract		

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Cost Estimate BOQ template with precise description of the items.

- Attached in the appendix

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References

- Information on this unit of competence, refer to the Cost Estimation Manual for Bridge Repair.

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