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Date: 08/03/2018

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Sub: Manual of inspection and routine maintenance of departmental bridges .

The undersigned is directed to inform that the Dam Safety Organization has prepared a guideline to be followed for routine inspection and maintenance of the departmental bridges to ensure safety. A copy of the same guideline is enclosed for taking necessary actions by the working divisions and reference.

Enclo: As stated.

08.03.18
(B. Mukhopadhyay)
Deputy Secretary to the
Govt. of West Bengal

IRRIGATION & WATERWAYS DIRECTORATE

GOVERNMENT OF WEST BENGAL

DAM SAFETY ORGANISATION

GUIDELINES FOR INSPECTION, REPAIR AND MAINTENANCE OF BRIDGES

NOVEMBER-2017

PREPARED BY

DAM SAFETY ORGANISATION

2ND FLOOR, JALASAMPAD BHAVAN, SALT LAKE

GUIDELINES FOR INSPECTION, REPAIR AND MAINTENANCE OF BRIDGES

Introduction:

Bridges represent a large financial investment and provide an essential service to the community and the economy. Regular inspection and maintenance of bridges are essential to address the defects in timely manner.

This guideline provides the basis for the management, inspection, maintenance and subsequent repair of bridges owned and maintained by I & W Department. The objective of this guideline is to provide engineers and other personnel of I & W Department responsible for inspection, maintenance & repair with a ready reference to recommended procedures. This guideline is intended to be a useful and practical document for bridge inspection maintenance personnel concerned of I & W Department.

Types of Bridges: Bridges are classified in accordance to their form of structure and construction material and technology.

Structural forms normally used and as have been adopted for our bridges are

i) Arches
ii) Simply supported spans
iii) Continuous spans
iv) Rigid frame type with decking integral with substructure
v) Cantilever or balanced cantilever spans

Considering construction materials and construction technology, bridges are

i) Masonry.
ii) R.C.C.
iii) Pre-stressed Concrete.
iv) Steel girder bridges with plate girders or triangulated truss with built up members, supporting an RCC deck slab.
v) Composite construction for medium spans using plate girders and RCC deck slab.

vi) Timber bridges for temporary crossing and bridges for lighter loads either as cantilevers or in timber truss and timber deck arrangement

Problems With Different Bridge Material :

A) Timber :

The main problem with timber bridges are "Decay" and "Insect Attack". There are two portion of Timber one is "Heartwood" another is "Sapwood". The Sapwood is softer and lighter than the Heartwood.

Sapwood is prone to decay by insect attack. *Moisture content should be controlled (by seasoning) before using the timber as structural member of Timber Bridge***.**

Barks usually decay due to insect attack. *Therefore it is necessary to remove the bark from the timber in the bridge.*

Timber is also decay by fungus attack. Fungus attack mainly observed in the damp wood. It makes the wood soft and lose strength. Mainly parts in contact with ground (piles, ends of beam etc.), where dirt, debris and water collect and where vegetation grows, where fixtures are attached with deep bolts, water can get into the centres of the member is the favorable area for fungi attack.

Creosote(coaltar) is an oil-borne derivative of coal, which in the past has been widely applied for preventive treatment of timbers in ground contact or exposed to weather conditions. It protects the timber both against fungal and insect attacks. Creosote gives the timber a blackish colour and exudes a pungent smell, which makes it unwanted for inside use.

One of the most crucial damage of timber is done by termites and borers. Borers may be marine or land based. Marine borers usually cause severe damage and *all piers and piles in the salt water must be inspected regularly for these*. *CCA(Chromium-Copper-Arsenate) is also water-borne and exists in various formulations with different kinds of chemicals. CCA has been widely and successfully used in the tropics, since it gives an effective and long lasting protection against a wide range of wood destroying organisms including termites. In ground contact the protection is limited*

There are three simple tests for decay and attack by insect: (As per IRC :SP:52 – 1999)

A.) **Spike Test :**

A square spike is pushed into the wood to find soft spots. Square spike ensures that the resultant hole is not confused with insect bore-holes at a later date.

B.) **Hammer Test:**

Decayed timber sounds different from solid timber when hit with a hammer. The member is hit at different locations to find weak spots.

C.) **Drill Test :**

A 5mm. drill is used for this test. If any decay is suspected in the timber, a hole is drilled at such locations. The feel of drill will then reveal decay. Too many holes near the joints are ill-advised. After using spike or Drill test, holes should be plugged with wood- plugs after putting in some preservatives like creosote.

The points to be attend to concerning joints in the timber

1. Vibration caused by traffic or shrinkage can make bolts in the joint loose. Bolts should check for tightness.
2. Timber truss are mainly joint by nails. It is important to see that no gap is developed at any location.
3. Joints in the timber are usually made with steel plates and bolts and pins. Corrosion to the steel parts and bolts should be checked.
4. Loss of painting or surface protection should be noted.

B.) Brick Masonry Bridge:

Masonry is bricks, stones or concrete blocks put together with lime or sand cement mortar in the joints between them. It is very good in compression and weak in tension. It is mainly used for construction of substructure elements like abutments, piers and parapet walls. As there is no reinforced steel, there is no chance of corrosion. Vibration due to heavy loaded vehicle can cause damage to the masonry bridge.

The four main problems associated with masonry are:

1. Cracking

2. Bulging
3. Loss of pointing
4. Deterioration of brick, stone or concrete blocks.

1. <u>Cracking:</u>

Cracking is mainly caused due to movement of over loaded vehicle, alternate wetting and drying and temperature change. If crack occurs, plants and trees can grow in that cracks which may increase the crack width. Generally cracks pass through mortar joints, if cracks which cross bricks, stones or concrete blocks, usually serious. These cracks could be either over loading or by failure in foundation. All the cracks should be meticulously mapped and need to be repair immediately with cement mortar. Cracks is serious when it occurs near bearing, a step occurs in the face of masonry and if it is more than 5 mm and more wider.

2. <u>Bulging :</u>

Bulging is a change in shape i.e. curving of the face of a masonry wall. It is usually due to excessive back-pressure. Bulging of masonry parapet can be caused by vehicular impact. The force exerted by the soil behind a wall can increase due to saturation of fill if drainage is inadequate. For draining, weep holes are provided in the abutments and return walls. Sometimes these holes are chocked due to various reasons. This may happen due to movement of heavy loaded vehicle and compaction. Bulging should be mapped and measured with the help of a plumb-line. If the weep holes at the abutment and return walls are chocked immediate removal of chocking hole is suggested.

3. <u>Loss Of Pointing:</u>

Pointing is the mortar seen exposed between bricks or stones or concrete blocks. The mortar gets worn out by river or rain water. Pointing is usually gets weaker than stones or bricks and deteriorates with age. Loss or weakening of pointing can cause stones or bricks to move or even fall off. Re-pointing is suggested periodically.

4. <u>Deterioration of Bricks or Stones:</u>

Many weaker types of brick or stone cannot last for a long time. They can be worn away by rainwater or river flow. Peeling Off or De-lamination could be caused by alternate heating and cooling and changes in moisture content.

Tapping the stone or brick face lightly with a hammer can cause pieces to break off. This indicates that there is deterioration or weathering. It may then be necessary to protect the surface with a hard mortar, gunite or shotcrete.

C. Steel Bridge :

There are mainly six main problem associated with steel bridges. Which need detailed inspection.

1. Deterioration of paint or galvanizing / metalizing
2. Corrosion
3. Damage (bends or bulge) to steel parts
4. Loose bolts or pins or loss of weld
5. Cracking in plates
6. Loss of grease / oil from contact surfaces

1. **Deterioration of paint or galvanizing / metalizing**:

Steel corrodes when not protected from air or water. Protection is done by painting or metalizing or galvanizing. Sometimes painting is done after galvanizing or metalizing if risk of corrosion is high. Galvanizing is deposition of zinc on steel by a special process. Metalizing is spraying of zinc on steel by a special gun. In air, galvanizing provides more protection than paint. But in saline water, galvanizing or metalizing can peel off and rusting can occur.

Paint or galvanizing does not last for many years, if necessary cleaning is not done. When steel rusts, spot of rust are seen in the paint surface. Water enters through these spots and moves under the paint, causing peeling. Galvanizing or metalizing deteriorates due to corrosion of zinc. Proper records of spots at which paint or galvanizing has deteriorated should be maintained and timely repairs should be carried out.

2. **Corrosion:**

In contact with air and moisture, a chemical change occurs in steel and it is called rusting or corrosion. If corrosion progresses and becomes severe, the edge of plates appears to be split into thin layers. This is "Lamination". This is very serious for steel because steel looses almost all strength. Rust has a volume which is more than steel in actual form. Where two or more plates connected together, rust can push them apart due to increased volume and can bend the plates and or shear off the bolts, rivets or welds. Worst corrosion occurs where dirt, dust and water tend to accumulate under the deck. Birds dropping also can corrosion. Corrosion is mapped immediately and immediate necessary action is to be suggested for long service life for the steel bridges.

3. **Damage (bends or bulge) to steel part**:

Vehicle impact can made bend a member of a steel bridge. This may weaken the structure seriously. The location of the bend has to be mapped and the bend measured. Stiffness deck-plates may bend under overload. Immediate replacement of the weaker section is suggested.

4. **Loose bolts or pins or loss of weld:**

Steel plates are joined by fixing like rivets, bolts, or welds. All rivets and bolts must be tight and not broken. Corrosion can lead to breaking of rivets or bolts. By keeping a finger on one side of a rivet and lightly hammering on the other side, any looseness can be detected by the feel. There are two basic types of bolts, namely, bearing bolts and friction grip bolts. Friction grip bolt can be distinguished by marking on the head. Friction grip bolts are not likely to work loose and need not be checked. Bolts can be checked for tightness by means of a spanner. Each bolt or rivet on a bridge needs to be checked at every inspection, if it is observed loose immediate repair is suggested.

5. **Cracking in plates**:

It is not a usual problem but it occurs when heavy loaded vehicle passes through the bridge frequently. It may occur due to problem with welds or misfits, and faults in the steel can cause cracks. A careful look at all welds and holes is required as cracks can often start. A crack only in the paint is not serious, but if there is a thin line of rust along it, the crack is usually serious. Every crack should be mapped and its thickness measured with a crack gauge film. Immediate repair is suggested.

6.

7. **Loss of grease / oil from contact surfaces:**

Loss of grease / oil from contact surfaces can sometimes occur, leading to greater frictional forces, losses of metal and protection, and corrosion.

D. Concrete Bridge:

Concrete is made from coarse aggregate, sand cement and water. It is strong in compression and weak in tension. To carry tension steel bars are provided as reinforcing material. The steel so provided may be tensioned (as in pre-stressed concrete) or un-tensioned in (reinforced concrete). As concrete dries it always shrinks.

There are some of the main problems associated with concrete bridges:

1. Cracking
2. Spalling.
3. Corrosion of tensioned or un-tensioned reinforcement steel
4. Erosion and attrition
5. Chemical attack.

1. Cracking:

Cracking in concrete usually develops due to various reasons. One of the main reason is shrinkage. Fine and short cracks may not pose problems but wide and long cracks can always be dangerous. Shrinkage cracks are usually fine. These need not be mapped.

For mapping concrete cracks following guideline should be adequate:

i.) Measure the length and the maximum width of important cracks and draw them on a sketch.

ii.) Cracks 1mm. or wider are usually important. Smaller cracks are important if it occurs in important parts of the member. A simple metal gauge or crack-gauge film is all that is needed to measure crack widths.

iii.) Cracking or a large number of cracks in a small area should be mapped even if cracks are less than 1 mm. in width.

iv.) Rust staining or white deposit or discolouration along the line of cracks should be noted.

After mapping the cracks it is to be repaired immediately with mortar or cement slurry having high percentage of cement, otherwise crack width may wider due to various reason.

2. **Spalling:**

   If some of the concrete in the structure falls away, it is termed spalling of the concrete. It is mainly caused by corrosion of the reinforcement. When steel corrosion occur then its volume increase and the resulting pressure breaks away or spalls pieces of concrete. Spalling causes a loss in cross- section of member and consequent reduction in strength at the location.

   If concrete spalls then rusted reinforcement may be replaced or may coat with an epoxy film. After that concreting is to be done in that area with high percentage of cement and proper curing is suggested. Otherwise it may show some surface cracks due to shrinkage.

3. **Corrosion of tensioned or un-tensioned reinforcement steel:**

   It is a serious problem and can cause a bridge to fail if neglected. Corrosion is caused by water and air getting into concrete and reaching the reinforcement. It is accelerated by the presence of chemicals likes salts carried in water. Ingress of water and air is facilitated by a break in concrete due to cracking, spalling, or honey- combing or due to permeable, poor quality concrete, and or because of inadequate cover to reinforcement.

   a. Exposed reinforcement
   b. Occurrence of spalling
   c. Cracks or rust-strains (discoloration) or leach-marks along lines of reinforcement.

   If corrosion occur immediate repair with epoxy coating is suggested.

4. **Erosion and attrition:**

   Concrete of poor quality could be honey-combed, could be permeable, may be starved of cement, may not have specified construction tolerances, may have reacting aggregates and could, therefore, be susceptible to chemical attack. Usually, tests of cores establish permeability, cement content, reactive aggregates or proneness to chemical attack. But a honey-comb concrete easily can be detected by naked eye and indicates concrete is weak in strength. Immediate repair is suggested.

5. **Chemical attack.**

   Even without the presence of moss, if the surface of the concrete feels soft and slippery, and if there are a number of small hollows in the surface of the concrete, it can be inferred that chemicals are damaging the concrete. Tests are required to be conducted to determine the depth of carbonation and the extent of attack by chemicals.

If chemical attacks occur then immediate repair is suggested.

Types of damages to various components of bridges due to natural causes and protection measures against them:

Damage Caused by River:

The water flowing in a river can pick up material from the river bed or banks and carry it away. This is called "SCOUR". Scour can create large holes in the river bed or can wash away large sections of banks.

Bridges are damaged either when river changes its course or when it is not able to go through the waterway provided.

a.) The waterway provided is inadequate for the discharge in the river.
b.) Waterway blocked by deposition in the bed, parts of old bridges, trees, bunds and other debris.

If a flood is too big for the waterway provided under a bridge, the following can occur:

i.) The river washes away the bridge.
ii.) It washes away the road embankment and may go round the bridge.
iii.) It washes away fill in front of abutments and may scour larger and deep holes in the river bed. If the provided waterway is not sufficient , additional spans or culverts may be provided to carry the extra flood water.

Protection against scour:

If a river is causing scour, the road embankment, the abutments and the piers need to be protected. It could be "bed protection" or " Slope protection".

Bed Protection:

To protect the bed from scour a part of bridge sites need to be covered at times. The cover is usually provided with the stone and concrete blocks pitching, concrete flooring or paving with stone filled boxes or creates.

Slope Protection:

Slope protection work is done usually in the form of stone pitching or boulder pitching. Embankment runs across the water mass flowing along the river banks, especially in rivers with the flat gorges and large flood spreads. Such embankment can breach unless protected adequately by stone pitching. Some embankment in the back water zone is to be designed for sudden draw-down.

River Training:

River can change their course, change of course after a time can damage a bridge. Debris or large logs can cause deposition of the bed material carried in suspension by the river. This leads formation of new island. Such an island form upstream of a bridge can cause scour around piers and abutments. To prevent a river from changing its course river training works are provided. These works generally keep a river on its course. Four ways commonly used for training rivers are:

i.) Walls made of steel or timber, sheet pile or stone filled crates.
ii.) Embankment protected by boulder pitching.
iii.) Groynes made from crates or boxes filled with stone or from timber or steel piles.
iv.) Trees protected by stone-filled crates or boxes.

Water:

Water can also damage bridge by following ways.

i.) Corrosion of steel bridge
ii.) Corrosion of reinforcement or pre-stressing steel in concrete bridges.
iii.) Decay in timber bridges.
iv.) Damage caused to masonry or stone pitching by water running down its surface.
v.) Bulging of walls caused by excessive pressure exerted by water retained due to blocked weep holes.
vi.) Washed embankments due to water running down.

Most of the damage can be prevented by providing good drainage channel and water proofing to the deck of bridges. Badly placed water spouts can cause corrosion and other damages. A good filter medium behind abutments and returns and adequate provision of weep – holes is a must.

Debris, Dirt and vegetation:

Dirt or debris hold water if they get collected on a bridge structure. The resultant dampness causes decay or deterioration. Vegetation can grow in these pockets and can damage a bridge.

Debris carried by the river sometimes collects against piers or abutments. This can cause blocking of waterway, leading ultimately to out flanking.

Earthquake:

Sometimes bridge can be damaged by earthquakes. Earthquakes can cause two common types of damage:

i.) Foundation failure causing abutments or piers to move.

ii.) Dislodging of superstructure from their bearings. In earthquake prone areas, measures to hold the superstructure in place are usually provided.

Landslides:

A landslide occurring directly on a bridge can cause a bridge to collapse. If a landslide takes place upstream of a bridge, water can built up behind it. After sometime the river can break through and wash away the bridge alone with the debris. This does not occur often but, to be safe , changes in the river on the upstream of a bridge should be watched with the aid of local enquiry during inspection.

Important facts to be noted during bridge inspection:

1. **Services :** Services may be electricity or telephonic cables or gas, oil, water or sewage pipes. If any damage to services are noticed, which could bad to damage to bridge like say leaking water pipe can deterioration to bridge structure, should be brought to notice of the staff or authorities in charge of services.

2. **Signs :** Signs indicating limits on height , width , speed , weight , number of axle etc. should be installed at every bridge. Signs should be easy to read, specially for the drivers. It should be ensured that vehicles not permitted on the bridge ply over it.

3. **Road approaches and protection :**

a.) It is necessary to check for scour at the base of embankment slopes. Slopes of approach embankment become unstable if scour takes place and consequently embankment fills slips down.

b.) It is necessary to check for erosion of the fill near the abutments and wing wall due to inadequate drainage of rain water on the approaches to bridges.

c.) Cracking of the road or the edge of the embankments behind abutments indicates that wall has moved. Any cracking of the road or edge of embankment has therefore be checked. Failure of embankment may be by formation of slip circle or by piping.

d.) Toe wall are usually provided at the end of embankment slopes to prevent scouring away. It is necessary to look for any 'away' movement of the toe wall. Movement of large sections of the wall are serious.

e.) It is necessary to look for cracks in the stone pitching provided on the slope surface. Pitching may crack due to settlements in embankment or due to poor mortar pointing. Pieces broken off from stone pitching indicate bad undermining.

4. **River bed protection:**

a.) It is necessary to make a note of large holes in the river bed near or directly under bridge.

If the river flow is fast and if river bed is soft , protection may be provided by:

i.) Stone pitching

ii.) Concrete cover slab or Concrete block pitching

iii.) Stone filled crates or boxes

iv.) Boulder pitching

b.) Scour in the river bed usually occurs at the edge of the bed protection or apron. If any scour holes go below the bed protection, the same may be noted and protected with suitable measures.

It is necessary to attend all cracks in reinforced concrete aprons but for the mass concrete or stone aprons, only large cracks need to be attended. For reinforced concrete aprons, corrosion of reinforcements should be looked into.

c.) Boulder re-pitching or garlanding is to be used to prevent scour around piers.

5. **Obstructions in the waterway:** The waterway under a bridge should be clear. Any obstruction can cause

    a.) Scour in the bed or banks.

    b.) Cause successively larger obstruction due to further deposition and entanglement of debris.

    It is therefore necessary to return debris piled up against piers and abutments or on the bed on the u/s side of the bridge.

6. **Change of river course**: If a river changes its course it can destroy a bridge especially when the change takes place at its upstream. To judge whether a river is changing its course, bends in the river u/s of a bridge and condition of banks on bends should be examined, duly considering information from the local people.

    If the bank is steep with the trees at the edge, but with nothing else growing on the bank, then it can be inferred that the river is shifting towards the bank. When a lot water is flowing but the bank is not steep and small plants are seen growing with some mud or pebbles on the bank, then it can be inferred that the river is shifting away from the bank. If new islands are forming on the u/s, it means the river is likely to change its course.

7. **Concrete abutments, wing walls and return walls:**

    a.) In concrete structures any cracking of concrete should be noted. Cracks are termed important if 1 mm or wider / and or if water seeps through them. Near the bearing even fine cracks are important.

    b.) 'Spalling' of concrete if any should be noted.

    c.) The areas where the quality of the concrete is poor, as apparent from honey-combing and / or chemical attack should be noted.

    d.) It is necessary to observe leach marks, rust marks, discolouration, leakage cracks and spalling to infer corrosion of reinforcements. At the location of spalling the colour of the reinforcement and the reduction in diameter of the exposed bar or its stage / of corrosion should be examined carefully.

8. **Masonry abutments and returns :**

    a.) In masonry all cracks wider than 3 mm at the widest location should be noted.

b.) Any cracks near bearings especially if these go all around the bearings, and cracks which run underneath the bearings are important and should be examined carefully.

c.) Bulges noticed in abutments are more serious than those noticed in returns. When a bulge has horizontal cracks in it, then it is a serious problem and should be examined carefully.

d.) Poor quality pointing or loss of pointing should be noted. Any deterioration of the bricks, stones or concrete blocks, should be observed and noted.

9. <u>Piers:</u>

a.) **<u>Concrete Piers:</u>** For piers built in concrete, it is necessary to inspect te following:

- i.) Cracking of concrete, especially around the bearings, in pile caps, wells and pier caps. Important cracks should be noted.
- ii.) Spalling of concrete should be noted.
- iii.) Corrosion of reinforcement with special attention given to rust stains from cracks and areas of spall concrete. If exposed, the loss in bar diameters should be measured.
- iv.) Areas of poor concrete especially showing honey combing and chemical attack.

b.) **<u>Masonry piers:</u>** for masonry piers, the following points to be inspected.

- i.) Cracking of masonry especially long and wide cracks and any cracks near bearing.
- ii.) Poor pointing can lead to problems. Brick or stone masonry piers can be seriously weakened by loss of mortar pointing by erosion due to river flow.
- iii.) Poor condition of bricks or stones.

c.) **<u>Steel Piers:</u>** steel piers are normally in piers, it is necessary to inspect for:

- i.) Debris in the joint of the steelwork, leading to corrosion.
- ii.) Deterioration of paint or galvanizing or metalizing.
- iii.) Corrosion in the portion between HTL and LTL.
- iv.) Bends in steel members and joints.
- v.) Loose bolts or rivets and lost welds or cracks near welds and bolt holes.
- vi.) Cracking specially near bearings

d.) **<u>Timber Piers:</u>** for timber piers, it is necessary to inspect for,

i.) Debris in the joints.

ii.) Decay in the joints and near water levels.

iii.) Insect attack especially below water level in salt water. Attack of marine bore is very common here.

iv.) Splits in the timber, especially near bolt holes and at or below water level.

v.) Loose bolts or pins at joint.

vi.) Bends in timber, which may be caused by impact or overloads

vii.) Corrosion of steel parts especially at water level.

10. **<u>Superstructure</u>**:

a.) <u>General:</u> The following points need to be checked during general inspection:

i.) Impact damage to beams, trusses or bracings caused by vehicle, boats or logs.

ii.) Debris and vegetation on beams, trusses, bracings or in joints.

iii.) Water coming through the bridge deck, signs of wetness on steel work on timber and on concrete respectively in the form of rust marks, water run marks, and dark areas with buildup of white material on surface.

iv.) Excessive deflection in superstructure.

v.) Cracking and spalling in superstructure.

b.) <u>Concrete girders:</u> for concrete girders, it is important to look for the followings :

i.) Cracks at the end of beams which spread up from the bearing seat. It is a serious problem.

ii.) Spalling of concrete which may due to external impact or corrosion of reinforcement.

iii.) Signs of corrosion of reinforcement. If any reinforcement is visible, loss of diameter of the bar should be noted.

iv.) Signs of poor quality of concrete especially at the corners of bottom bulbs.

c.) <u>Steel girders:</u>

For steel girders it is important to look for the following:

i.) Deterioration of paint or galvanizing or metalizing on all main and cross girders.

ii.) Ends of the beams and girders get badly corroded and corrosion cause two very serious problem these are:

Lamination and steel sections forced apart by increase in volume due to rusting causing rivets bolts or welds to snap.

iii.) Bends in webs and flanges of girders and bends in stiffners and bracings. Serious overloading could cause bends along the length be measured by using straight line.

iv.) Loose bolts, rivets lost welds should be noted carefully.

v.) Cracks at the location of welds and holes should be noted. Cracking can be dangerous.

d.) <u>Steel trusses:</u> For steel trusses it is important to look for the following:

i.) Deterioration of paint, galvanizing or metalizing especially at joints.

ii.) Corrosion normally starts at joints. The joints of the bottom chord are affected first. Where corrosion is apparent, lamination should be looked for. Signs of forcing apart of plates should also be noted.

iii.) Any bends in turns member should be noted.

iv.) Damaged or bent joints should be checked carefully.

v.) Bent or damage bracings should be noted.

vi.) Loose bolts / rivets and lost welds should be noted.

vii.) Cracks in trusses are dangerous and should be reported to the higher authorities as soon as possible.

e.) <u>Timber decks:</u> for the timber decks attention should be given to the following points.

i.) Areas of dampness and locations around nails and spike should be closely inspected for decay. If beam rest on the ground or likely to come in contact with soil, the ends decay faster. The ends of beams should be carefully inspected for decay. Logs having bark place should be inspected very carefully and barks should be removed whenever possible without endangering safety.

ii.) The extent of insect attack should be assessed and noted. The spike test, hammer test, or drill tests should be used. The size and bad areas should be ascertained upto a point where good timber is encountered.

iii.) Splitting of timber is dangerous and should be checked carefully and attended with importance.

11.) **Masonry arches:** for masonry arches the most important observation is the change in shape of the arch. This could be observed in the following manner.

i.) Standing a long distance away compare the shape on the left of the arch center with that on that on the right.

ii.) Look for any shift in keystone at center of the face wall.

iii.) From underneath the arch look for any change in shape of barrel, even locally.

iv.) The arch barrel should be checked for any cracking. Cracks across the roadway are usually dangerous sign. Other important crack due to separation of the face wall from the arch barrel. These cracks run in traffic direction.

v.) Spandrel or face wall should be checked.

vi.)Quality and loss of pointing should be checked.

vii) Excessive leakage through arch should be noted and attended.

Procedure to be adopted for bridge repair and maintenance:

Preventive maintenance of Concrete Decks.

A. Recommended method :

1. To keep the deck clean and provide good surface drainage by keeping the drain open.

2. To monitor the condition by testing for chloride penetration, delamination and active corrosion.

3. Seal or overlay the surface to prevent and reduce salts and moisture penetration.

4. Seal cracks to prevent and reduce corrosion of the reinforcement steel.

5. Remove and replace (patch) deteriorated concrete.

Concrete Deck Sealing

Sealing is accomplished by providing a deck with a barrier to prevent chloride penetration of the deck. There are many types of sealers available in the market. The surface must be cleaned prior to application.

Concrete Deck patching

The need for deck patching is almost always caused by corrosion of the reinforcement. Deck patching is a temporary repair unless all chloride contaminated concrete is removed before the deck is patched. For permanent patching an in depth deck inspection is required to accurately identify the extent and limits of the contaminated concrete.

However potholes on the deck cannot be tolerated as rough decks increase the vehicular impact of the bridge which accelerates the damage and may contribute to the structural damage as well.

Recommended method for patching

1.Assess areas for patching using hammers. Delaminated areas will have a distinct hollow sound.

2. Outline the area to be patched allowing some extra edge areas for undetected delamination to facilitate the use of a concrete saw. Corners should be square (no feathered edges).

3. Usually a concrete saw is used to saw vertically for about 3/4 inch around the perimeter of the hole. Care must be taken not to cut any reinforcing steel in the deck. If patches are within 2 feet of each other, they should be combined.

4. Using hand tools and pneumatic hammers remove the concrete within the designated area. Fracture line over a reinforcing bar indicates an area that will soon spall and should be removed.

5. The area to be patched should be cleaned thoroughly using sand blasting or water blasting to remove any loose concrete, rust, oil or other contaminants.

6. If reinforcing steel has lost over 20% of its original cross section, new steel should be added by over lapping, welding etc.

7. Patching is normally grouped in to three categories based on depth:

a) Type A is above the top layer of reinforcing steel.

b) Type B is for deck surface to at least 1 inch below the top mat of rebars.

c) Type C is full deck depth.

8. Type A patching may require special aggregate size in that the diameter of the rock cannot be larger than the depth of the hole. Rebars will not be involved. Epoxy patches in particular and polymer materiel patches in general should be placed and consolidated in layers of limited thickness as recommended by the formulator.

9. Type B patching will involve rebars and it is important that space be left under the bars to allow fresh concrete to flow below beneath them so no voids are left underneath. Type B patching will be done alone by epoxy mortar in layers.

10. Type C patching will involve form work to support the bottom of the patch. If any type C patch is expected to exceed a 4'×4' area, the bridge expert should be consulted with as bridge strength maybe affected. Best option is to use batched concrete with properties similar to the parent concrete.

Crack Sealing

Crack sealing is important of concrete deck maintenance the most common causes of concrete deck cracks are listed below.

1. Transverse crack are often caused by thermal and or drying shrinkage of the concrete.

2. Transverse may also be caused by flexure of the deck or lack of cover on the reinforcement.

3. Longitudinal cracks are common over the joints. The cracks are caused by non uniform bending action of the beams under traffic. Longitudinal cracks are also occur over the longitudinal beams when beams spacing is large and deck bends over the beam.

4. Foundation settlement can cause a twisting force on a Concrete deck that generally results in a diagonal cracking pattern.

5. Thermal expansion caused by a high temperature combined with debris filled expansion joint can cause deck cracking or spalling, near expansion joint.

Small cracks repair

Small cracks can be filled by some of the liquid sealers on the market to waterproof decks. These products should be considered for use over the entire deck when cracks are numerous.

Dormant cracks repair

A cracks sealing material such as epoxy or polyurethane can be pressure injected into larger dormant cracks. This is done by drilling holes (ports) along the cracks and injecting the sealant through those entry ports. The maximum port spacing should not exceed the depth of the cracks. Prior to injection, the surface of the crack should be sealed. The sealing of the surface is usually done by brushing and epoxy along the surface of the cracks and allowing it to harden. If the injection pressure is extremely high, the sealing of crack surface may be done by v-grooving the crack and filling the groove with epoxy mortar. Since some deck cracks are likely full depth, they must be closed from below, before they are pressure injected from top. This may be done by brushing and epoxy along the crack from below. Before injection it should be ensured that cracks are cleaned by vacuuming or air blasting or water blasting or chemical washing and flushing.

Working Cracks Repair

If the crack is opon and shows evidence of movement, if it has been sealed before and has failed again or if there is evidence of recent re-cracking such as dust or surface regrout failure, it is a working crack and should be sealed with flexible crack sealer. Usually, this involves cutting a slot with sufficient width over the crack to hold the sealer. The sealer maybe hot or cold poured flexible materials.

Concrete Railing Repair

The concrete railing is as susceptible to cracks and spalls as the deck . The methods of crack seal can be used on the railing as on the deck.

Repair and Maintenance of Bearings

Bearings transmit the dead load of the superstructure and the live load to the substructure (abutments and piers) while permitting the superstructure to undergo the necessary movements without developing overstresses . The movements are caused by temperature change, wind pressure, substructure movement and the deflections from the loading. A bearing that is so badly corroded or fouled that the parts will not move relative to each other , as originally intended , is said to be frozen. A bearing assembly that is frozen , out of position , damaged or otherwise inadequate , may over stress the bridge seat, beam ends, columns or others members of the bridge and must be repaired or replaced.

<u>1.Cleaning- Recommended method</u>

a) Clean with high pressure water/air or mechanical devices.

b) Thoroughly flush all bearings and bearing seats at piers and abutments with high pressure water/air to remove dirt and debris.

c) Scrap brush or chip all accumulated debris that cannot be removed by high pressure water/air flushing.

<u>2. Spot painting</u>

All corroded areas are to be cleaned by an approved methods and then painted with any approved oil based paint or Inorganic zinc paint.

<u>3. Sliding Plates</u>

The most common problem with sliding plates is friction caused by corrosion. The friction can transmit enough force to the anchor bolts to crack the bridge seat. If bearing is corroded or movement is prohibited, the bridge must be Jacked so that plate surface can be removed, thoroughly cleaned, lubricated and repositioned.

<u>4. Rollers</u>

Most roller bearing nests are enclosed and maintenance is difficult. If the rollers stop functioning they must be removed and refurbished. To accomplished this, the end of the span must be jacked.

Since the roller nests normally have to be rebuit in a shop, it is desirable to fabricate an extra one to avoid closing the bridge for extended period of time.

5. **<u>Elastomeric Pads</u>**

Maintenance is rarely required unless the bearing pad fails or walks out of position. To correct these problems the bridge must be jacked and the elastomeric pad replaced or repositioned.

Concrete Beam & Girder Repair:

1.Crack repair by epoxy injection

a)Clean the cracks by air or brush.

b)Install the ports along the crack and seal all other cracks with epoxy.

c)After the sealing is cured , pumping of epoxy into the 1st port is began.

d) Continue pumping until epoxy blow from a second port.

e) Seal the 1st port, then begin pumping at the 2nd port.

f) Repeat steps b, c, & d until all ports are full.

g) Remove ports and surface seal after epoxy has cured.

2. **Penetrant sealer**

a) The concrete surface shall be prepared for sealing by using high pressure water blasting to remove all traces of dirt, mineral deposits and all other deleterious materials.

b) Apply penetrant sealer in accordance with the specification and the manufacture's recommendation.

3. Dry packing

Dry pack can be use for filling narrow slots cut for the repair of dormant cracks. Repair the crack by hand placement of low water cement mortar followed by tamping or ramming of the mortars into place. The use of dry pack is not recommended for active cracks.

a)Before a crack can be repaired dry packing the portion adjacent to the surface should be widened to a slot about 1 inch width and 1 inch depth using a power driven saw tooth bit. The slot should be undercut so that the base width is slightly greater than the surface width.

b) Clean the slot thoroughly.

c) Apply bond coat, consisting of cement slurry or equal quantities of cement and fine sand, mixed with water to a fluid paste consistency.

d) Make the mortar mix consisting of 1 part cement, three parts sands and just enough water so that the mortar will stick together when hand molded in to a ball.

e) To minimize shrinkage in place, the mortar should stand for 30 minutes after mixing and then remixed prior to use.

f) The dry packing should be placed in layers about 3/8 inch thick. Each layer should be thoroughly compacted over the entire surface using a blunt stick or hammer. Each layer should be scratched to improve bonding with the next layer. There is no need for waiting period between applications of layers.

g) Finish the top surface and repair should be cured by either water or curing compound.

4. Shear Crack Stitching

Reinforced concrete T beam often exhibit diagonal shear cracks near the ends of the beams (at the supports). The cracks begin at the base of the beam section, near the bearing and travel upward towards the middle of the beam span, at approximately a 45 degree angle. Typical hairline cracks do not require repair. However numerous large cracks (wide) can be repaired by post reinforcement (stitching) method.

A. Locate and seal all the cracks (wide) with epoxy sealing materials.
B. Mark the beam center line on the top of the deck.
C. Locate the transverse deck reinforcement.
D. Vacuum drill a series of 45 degrees hole, that avoid the rebars. The direction of drilling is perpendicular to the shear cracks and the spacing varies approximately 6 to 12 inches between holes.
E. Pump the holes and cracks full of epoxy.
F. Insert reinforcing bars into the epoxy filled holes.
G. Seal holes with epoxy grout.

5. Spall repair –Beam end

This procedure may be used to repair deteriorated ends of concrete beams. Such deterioration is usually caused by excessive thermal forces from frozen bearings. This is a common problem on old T beam bridges, which often lacked adequate reinforcement in the beam ends. This type of repair is not required if the bearing area of the beam end is not affected.

a) Restrict traffic from the affected beam.
b) Jack Remove the deteriorated concrete.
c) Epoxy inject at any visible cracks.
d) Place the new reinforcements and secured to the existing reinforcement steel by welding or mechanical splices.
e) Apply epoxy bonding compound to prepare the surfaces of the beam end.
f) Place the new concrete. A non shrink additive should be used in the new concrete.
g) After concrete has reached sufficient strength, jack all beams simultaneously to sufficient height to install new elastomeric bearing pads.
h) Uniformly lower the end of the bridge. Check for possible distress in the repaired area.
i) the beam off the support enough to slide a piece of sheet metal under the beam.

Abutment repairs

1) Abutment face repair - The concrete inabutments may deteriorate from the effects of water, sea salt and debris impact. This condition requires that repairs be made to prevent continued deterioration particularly increased spalling due to moisture reaching the rebar and causing corrosion.

   Recommended method is as follows:-

   a) Remove deteriorated concrete and laitances by chipping and blast cleaning.
   b) Drill and set tie screws and log studs to support the form work.
   c) Set reinforcing steel and forms.
   d) Apply epoxy bonding agent to the concrete surface just before placing the concrete.
   e) Place the concrete,cure and remove the forms.
   f) Tensile cracking of abutment walls:

      If the abetment was designed incorrectly it may prove to be structurally insufficient and produce tensile crack along the length of the abutment. These cracks have the potential to cause a complete failure of the abutment and should be treated as a serious concern.

A wall of sheet pile can be placed behind the abutment in order to resist the majority of the lateral earth pressure. Special attentions should be paid to the sizing of the sheet piles, so they adequately protect the abutment. A stitching repair may be provided for the tensile cracking.

The other solution is to create a new wall in front of the existing abutment and installing a tie back system that extends through the existing abutment.

Suitable method may be used according to the site condition.

Wing wall repair:-

1) Concrete wing wall repairs: Repair the concrete wing walls by removing deteriorated portions of the wall and replace with new concrete.

   Recommended method:-

   a) Excavates as required to set dowels and forms.
   b) Remove all fractured or deteriorated concrete to sound concrete by chipping and blast clean to remove laitances.
   c) Drill and set form anchor bolts and dowels. Dowels are to be placed a minimum of 9 inches into sound concrete and set with non shrink grout or approved adhesive.
   d) Just prior to placing concrete, apply epoxy bonding agent to all existing concrete that is to come into contact with new concrete.
   e) Cure concrete until concrete has developed sufficient strength to resist the imposed lateral pressure before back filling with granular materials.
   f) Backfill with granular materials.

Pier repairs

1) Repair of deteriorated concrete – Recommended method.

   a.) Saw cut the boundaries of the deteriorated concrete to be removed to a depth of ¾ inch.

   b.) Remove deteriorated concrete by chipping with lights power tools.

c.) Blast clean exposed reinforcing bars of all rust and foreign materials. Replace deteriorated bar sections as required.

d.) Place reinforcing mess as required.

e)Blast clean the existing concrete to be patched to remove loose concrete chips and

laitance.

f.) Place forms, coat existing concrete surfaces with epoxy bonding agent, and place concrete.

g.) Remove forms and finish surfaces after the concrete has cured.

Repair of cracked Piers

1. Vee Crack repair – A footing may crack transversely due to uneven settlement of the pier or abutment. This will often be accompanied by a crack continuing up through the pier (or abutment). It is advisable to seal the crack to prevent further intrusion of silt, debris and water that will attack the reinforcing steel. If the crack is not moving it can be bonded together again.

   Cracks in substructures are generally vertical. The most effective method of repairing these cracks is epoxy injection. In order to get maximum penetration of the epoxy filler, the first injection is made at the bottom of the crack. Starting at the bottom and moving up in gradual increments towards the top increases the pressure needed to apply the epoxy and should result in greater crack filling penetration.

   Another method that prevents moisture from entering the crack is to vee the opening and fill with grout.

   The procedure is as follows-

   a) Cut a vee shaped groove at the surface along the crack approximately 2 to 3 inches in width using a small pneumatic chisel.
   b) Thoroughly flush and blow out the crack using water and high pressure air.

c) Secure a retaining form on the face of the concrete surface over the vertical portion of the crack.
d) Wet the surfaces of the crack thoroughly by pouring liberal quantities of water into it. Fill the crack with a cement (or epoxy) and fine sand grout in a 1:2 mix that runs freely.
e) Clean out the Vee's portion of the surface after the grout has partially set and apply bonding compound and neat cement based to the surface of the Vee; then feel the vee with a stiff grout mixture.

Concrete pile repair:

Depending upon the design of the bridge, it can be difficult to inspect most, if not all, of the pile. Due to inability to observe deterioration when it begins, underpinning needs to be considered if complete bearing is lost before the pile can be adequately repaired. The most important concept is to address why the deterioration occurred. If the repair replaces cross section but does not consider the source of the deteriorations it will not be effective.

Pile jackets – If concrete pile is severely deteriorated and pile replacement is not viable,the deteriorated portions of the pile can be encased in new concrete using a fibre glass or steel form jacket. Fibre glass jackets are frequently used because it does not require dewatering and are effective in all water types and involve a relatively simple installation. There are 2 common fibre glass piles repairs that are conducted based on deterioration of the existing pile.

If the sections loss of the existing pile is less than 25% then a ½ inch annular void created between the piles and the fibre glass jacket. The void is then filled with moisture insensitive epoxy grout. If the section loss is more than 25 % then a minimum 2 inch annular void is created between the fibre glass jacket and the pile. The bottom 6" and top 4"of the void are filled with the same moisture insensitive epoxy grout. The rest of the void is filled with a non segregating cement grout. The fibreglass and moisture insensitive epoxy grout provide an impermeable barrier that will protect the cement grout.

The basic construction procedure is listed below:-

a) Clean the surface of the pile where the jackets are to be installed.
b) Install a reinforcing cage around the pile; use spacers to keep the reinforcements in place.

c) Place the forming jackets around the pile and seal the bottom of the form.

d) Pump the concrete into the form through the opening at the top.

e) Finish top portion of the repaired area, the top surface of the pile jacket should be sloped to allow runoff.

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