# Bridge Maintenance and Repair

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Mark Rossow, PhD, PE

Continuing Education and Development, Inc.
22 Stonewall Court
Woodcliff Lake, NJ 07677

P: (877) 322-5800
info@cedengineering.com

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# BRIDGE INSPECTION, MAINTENANCE, AND REPAIR



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# BRIDGE INSPECTION, MAINTENANCE, AND REPAIR



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# CHAPTER 10

# GENERAL PREVENTIVE MAINTENANCE, REPAIR, AND UPGRADE

## Section I. INTRODUCTION

### 10-1. General

With the cost of constructing and replacing bridges escalating every day, it is imperative that we make the most out of our existing bridges. The formula for doing this is: properly maintaining each bridge to extend its service life, immediately repairing any structural damage or deterioration of the bridge to prevent increased damage or deterioration, and upgrading the load capacity of the structure to meet the future increased traffic requirements. The specific categories of bridge maintenance, repair, and upgrade are discussed in the following paragraphs.

### 10-2. Preventive maintenance

Maintenance is the recurrent day-to-day, periodic, or scheduled work that is required to preserve or restore a bridge to such a condition that it can be effectively utilized for its designed purpose. It includes work undertaken to prevent damage to or deterioration of a bridge that otherwise ‘would be more costly to restore. The concept of preventive maintenance involves repair of small or potential problems in a timely manner so that they will not develop into expensive bridge replacements. Preventive maintenance activities can be divided into two groups: those performed at specified intervals and those performed as needed.

*a. Specified interval maintenance.* This group includes the systematic servicing of bridges on a scheduled basis. The interval varies according to the type of work or activity. Tasks identified as interval maintenance can be incorporated into a maintenance schedule for that bridge. Examples are:

(1) Cleaning drainage facilities.
(2) Cleaning and resealing expansion joints.
(3) Cleaning expansion bearing assemblies.

*b. As-needed maintenance.* These activities are performed when the need is foreseen for remedial work to prevent further deterioration or the development of defects. The need for this type of maintenance is often related to the environment or identified during inspections. Example activities include:

(1) Sealing concrete decks.
(2) Painting steel members.
(3) Snow and ice removal.

### 10-3. Replacement

The replacement of bridge member components is based on the material of the existing member, equipment availability, and the training level of the repair crews. More detailed considerations for the replacement of each type of bridge member are provided in section III of chapters 11 through 13.

### 10-4. Repair

Bridge repair is actually an extension of a good maintenance program. It involves maintaining the bridge’s current structural load classification. Selection of the correct repair technique for a bridge of any type and material depends upon knowing the cause of a deficiency and not its symptoms. If the cause of a deficiency is understood, it is more likely that the correct repair method will be selected and that the repair will be successful. A general procedure to follow for designing and executing a repair involves the evaluation and determination of the causes for the deficiency and the methods, materials, and plans to be used in the execution of the repair.

*a. Evaluation.* The first step is to evaluate the current condition of the structure. Items to include in the evaluation are:

(1) Review of design and construction documents.
(2) Review of structural instrumentation data.
(3) Review of past bridge inspections.
(4) Visual examination, nondestructive test, and laboratory test.

*b. Relate observations to causes.* Evaluation information must be related to the mechanism or mechanisms that caused the damage. Since many deficiencies are caused by more than one mechanism, a basic understanding of the causes of deterioration is needed to determine the actual damage causing mechanism.

*c. Select methods and materials.* Once the underlying cause of the structural damage is determined, selection of appropriate repair materials and methods should be based on these considerations:

(1) Determine prerepair adjustments or modifications required to remedy the cause, such as changing the water drainage pattern, correcting

differential foundation subsidence, and eliminating causes of cavitation damage.

(2) Determine constraints such as access to the structure, the operating schedule of the structure, and weather.

(3) Determine permanent/temporary repair advantages/disadvantages.

(4) Determine the available repair materials and methods and the technical feasibility of using them.

(5) Determine the most economically viable, technically feasible methods and materials. Select the combination that ensures a satisfactory job.

*d. Prepare design memoranda, plans, and specifications.* This step should be based on existing guide specifications, enhanced by incorporating experience gained from similar projects, and allowing as much flexibility with regard to materials as possible.

*e. Execute the repair.* The success of the repair depends on the degree to which the repair is executed in conformance with the plans and specifications.

### 10-5. Bridge upgrade

*a. General.* The upgrading of existing bridges is usually required where they are to carry heavier live loads than those for which they were designed. Upgrading or strengthening may also be required because of inadequate design or as the result of localized deterioration. The decision to upgrade a bridge or to replace it should take into account the age of the structure, the material of which the various members are made, the fatigue effect of the live loading, the comparative estimated cost, the added service life of the upgraded bridge, and the possible future increase in the live loading.

*b. Upgrade levels.* The upgrade of a bridge structure can be carried out at three levels.

(1) Strengthening of the existing individual components of the bridge to provide a moderate increase of the bridge's load carrying capacity.

(2) Redesigning the structure by adding components (stringers, piers, load bearing decks, etc.).

(3) Redesigning the structure by a combination of strengthening existing components and adding components to increase the load capacity.

## Section II. COMMON MAINTENANCE TASKS

### 10-6. General

There are numerous different types of bridges and materials of which these bridges are constructed. However, there are some maintenance tasks that are common to all bridges despite their individual designs and construction materials. These tasks are incorporated into standardized maintenance operating procedures and generally involve keeping the bridge clean and conducting work and minor repairs to prevent bridge deterioration.

### 10-7. Cleaning deck drains

Drains and scuppers should be open and clear to ensure that the deck drains properly and that water does not pond. Ponding of water on the deck increases the dead load on the bridge and presents a hazard to drivers in the form hydroplaning. Proper drainage also helps prevent water from leaking through the deck or deck joints and causing deterioration of other superstructure components.

### 10-8. Ice and snow removal

The primary reason for the removal of snow and ice is to provide a safe bridge for motorists. Bridges are generally the first portion of the road network to ice over and require immediate attention in freezing weather. The primary means to combat the accumulation of snow and ice is plowing the snow from the traffic lane of the bridge, spreading abrasives (crushed rock, sand, cinders, etc.) to improve the wheel traction, and chemicals (see table 10-1) to lower the freezing point of the water on the deck. When deicing salts (calcium chloride or sodium chloride) are used as part of this process, it is imperative that the maintenance schedule includes cleaning the bridge in the spring to remove any lasting effects of the salts. Any abrasives used on the structure should be removed as soon as possible after the snow period is over to reduce wear on the deck.

### 10-9. Bank restoration

Bank restoration involves the area in and around the abutments and up to the waterline. Erosion is the biggest problem and a maintenance program should include filling in washouts and seeding or using riprap to help prevent erosion. For a more detailed description on the use of fill and riprap, refer to paragraph 10-18d.

### 10-10. Traffic control items

It is important that traffic control items (clearances, load classifications, speed signs, centerlines, etc.) be maintained on a regular basis to control the traffic across the bridge. It is especially impor-

Table 10-1. Chemical application rates

| Temperature | Conditions | Precipitation | Multilane Divided | Primary | Secondary | Instructions |
|---|---|---|---|---|---|---|
| 30 °F and above | Wet | Snow | 300 salt | 300 salt | 300 salt | - Wait at least 0.5 hr before plowing |
| | | Sleet or freezing rain | 200 salt | 200 salt | 200 salt | - Reapply as necessary |
| 25-30 °F | Wet | Snow or sleet | Initial at 400 salt repeat at 200 salt | Initial at 400 salt repeat at 200 salt | Initial at 400 salt repeat at 200 salt | - Wait at least 0.5 hr before plowing; repeat |
| | | Freezing rain | Initial at 300 salt repeat at 200 salt | Initial at 300 salt repeat at 200 salt | Initial at 300 salt repeat at 200 salt | - Repeat as necessary |
| 20-25 °F | Wet | Snow or sleet | Initial at 500 salt repeat at 250 salt | Initial at 500 salt repeat at 250 salt | 1,200 of 5:1 sand/ salt; repeat same | - Wait about 3/4 hr before plowing; repeat |
| | | Freezing rain | Initial at 400 salt repeat at 300 salt | Initial at 400 salt repeat at 300 salt | | - Repeat as necessary |
| 15-20 °F | Dry | Dry snow | Plow | Plow | Plow | - Treat hazardous areas with 1,200 of 20:1 sand/salt |
| | Wet | Wet snow or sleet | 500 of 3:1 salt/ calcium chloride | 500 of 3:1 salt/ calcium chloride | 1,200 of 5:1 sand | - Wait about 1 hr for plowing; continue plowing until storm ends; then repeat application |
| Below 15 °F | Dry | Dry snow | Plow | Plow | Plow | - Treat hazardous areas with 1,200 of 20:1 sand/salt |

note: Chemical application is in pounds per mile of 2-lane road or 2 lanes of divided.

tant for moveable bridges that navigation lights, traffic control systems, and protective fender systems be monitored regularly. This is a safety more than a structural issue; however, it constitutes an important component in providing a complete maintenance program.

## 10-11. Bearings and rollers

All rockers, pins, and rollers are to be kept free of debris and corrosion, lubricated where necessary, and maintained in good working order. Depending on the type of bearing (fixed or expansion), they should permit the superstructure to undergo necessary movements without developing harmful overstresses. A “frozen” or locked bearing that becomes incapable of movement allows the stresses generated to become excessive and may even cause a major failure in some affected member.

## 10-12. Debris and removal

*a. Superstructure.* Any debris left on the superstructure due to traffic or high water should be removed for safety reasons and to prevent deterioration in areas were the debris will trap moisture onto the superstructure.

*b. Substructure.* The substructure is susceptible to debris or floating ice that forms drifts against its components. This can cause premature deterioration of these components and place excessive lateral loads on the whole structure. The techniques available to remove drifts are:

(1) Clear small debris with a pole or hook.

(2) Pull large pieces of debris clear with a crane.

(3) Clear large and small pieces of debris with a powerboat.

(4) Blast large jams to break them up.

## 10-13. Bridge joint systems

*a. General.* Joints are designed to provide for rotation, translation, and transverse movements of the superstructure under live loading and thermal expansion. The system should also prevent water leakage onto the components below the bridge deck. The two common joint systems are open and closed joints.

*b. Open joints.* The open joint provides for longitudinal movement of the superstructure. The joint construction is not watertight and should permit traffic to cross smoothly.

(1) *Finger joints.* Interlocking steel fingers attached to a steel plate allow longitudinal but restrict transverse deck movements.

*(a) Clogged joint and drain trough.* Frequently flush and clean the joint and drainage system to remove debris accumulation in the system. This will also help prevent corrosion and concrete deterioration.

*(b) Loose joints.* Remove loose or faulty bolts or rivets, reposition the expansion device, and rebolt. It may be necessary to countersink the bolts or rivets to avoid future problems.

*(c) Broken finger joints.* Weld replacement fingers onto the joint.

*(d) Fingers closed.* Trim the expansion fingers or remove the system, reposition, and reinstall.

(2) *Armored joints.* These consist of steel angles at concrete edges which are left open or filled with a mastic or other material to prevent intrusion of debris. If the joints are clogged, clean out the joint, repair any broken angles, and apply a liquid polyurethane or preformed compression joint sealant for waterproofing and to prevent debris intrusion.

(3) *Sliding plate.* A horizontally positioned steel plate is anchored to the deck and allowed to slide across an angle anchored to the opposite face of the opening.

*(a) Clogged expansion gap.* Remove any dirt, debris, or asphalt from the gap to ensure that sliding plate interacts properly with its angle seat.

*(b) Joint closed.* Trim the steel plate.

*c. Closed joints.* The closed joint is a watertight arrangement of various materials which allow longitudinal movement of the superstructure.

(1) *Elastomeric.* A sealed, waterproof joint system which uses steel plates and angles molded into neoprene coverings to provide an anchorage and load transfer (figure 10-1).

*(a) Faulty section.* Remove and replace.

*(b) Inadequate seal.* Apply new sealant or remove and reinstall using proper sealing techniques.

*(c) Loose or broken bolts.* Remove broken bolts and replace with “J” bolts.

(2) *Compression seal.* Extruded neoprene with cross-sectional design and elasticity to provide for retention of its original shape. Leakage is the most common failure associated with this joint sealant and requires replacement of the deficient compression joint sealant (figure 10-1).

### 10-14. Scour protection

The excavation or removal of the soil foundation from beneath the substructure undermines the load carrying capacity of the bridge. It can also cause excessive settlement if proper preventive maintenance is not practiced. A foundation may be protected against scour in the initial design and after construction has been completed.

*a. Design.*

(1) Locate bents and piers parallel to the direction of the water flow.

(2) Use long piles driven to a depth which provides sufficient bearing and accounts for scouring.

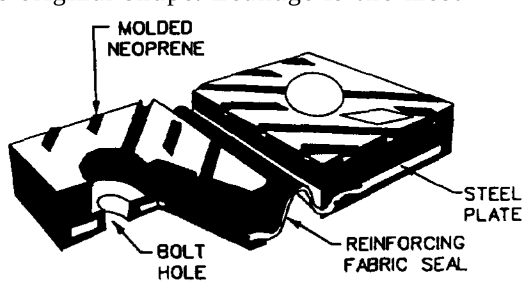
(3) Drive a row of closely spaced fender piles perpendicular to the stream flow at the upstream end of the substructure. This may not protect the downstream end since eddies and increased velocity may produce erosion on the downstream end. Their greatest effectiveness is for narrow piers and larger spans structures.

*b. After construction.*

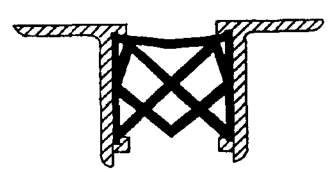
(1) Place sandbags around the base of bents, piers, and abutments, particularly at the upstream end.

(2) Place riprap consisting of stones weighing at least 50 pounds or bags filled with stones or cement.

(3) Divert drainage lines when scouring is due to local ground drainage or drainage from the deck itself.




MODEL INCORPORATING A GLAND TYPE OF JOINT SEALANT.



COMPRESSION JOINT SEAL MODIFIED WITH CORNER CLIPS

*Figure 10-1. Examples of closed joints.*

## Section III. COMMON REPAIR TASKS

### 10-15. General

Just as in maintenance tasks there are several repair tasks that apply to almost all bridges despite the materials used in construction. The purpose of bridge maintenance is to bring a bridge back up to original design load after damage or deterioration to the structure. These repairs can involve the strengthening, replacing, or adding support to the existing components of the structure. In the case of common repair tasks, these tasks generally involve repair to the foundation or substructure of the bridge.

## 10-16. Abutment stability

*a.* In addition to providing end support for the bridge deck, an abutment also acts as a retaining wall and is subject to horizontal earth pressures. These pressures coupled with the dynamic loading of vehicle traffic has the tendency to push out the abutment. If the abutment is unstable, it may be shored or fixed using guylines from shore anchorages or a deadman tie-back system.

*b.* The procedure for this process is as follows (figure 10-2): Emplace a deadman or drive a pile anchor approximately 3 feet on either side of the approach to the bridge. These anchors should be from 60 to 100 feet from the face of the existing abutment. Drill a hole in the wing-wall on both sides of the abutment and in a position outside and in line with the abutment cap. Run a restraining rod or cable from the deadman through the hole in the wall. Place a beam (example: steel wafer) on the outside of the cap. The beam must extend a distance at least greater than the position of the drilled holes in the wingwall on both sides of the abutment cap. Connect the retaining rod or cable to the beam and place tension on the rods or cables. This technique can be used on smaller abutments to help draw the abutment back to its original position and to hold it in place.

## 10-17. Drift and floating ice

Drift and floating ice place forces on the piers and frame bent of bridges. They can also cause structural damage to the cross section of the piles or columns of the system from the impact of the debris on the substructure. A common repair to minimize this problem is to install dolphins and/or fender systems upstream of the piers to adsorb the energy of the physical contact with the drift and to help break it up.

*a. Pile cluster dolphins.* This type of dolphin consists of a cluster of piles with the tops pulled together and fixed into position (figure 10-3). Dolphins can be constructed from:

(1) *Timber.* The top is lashed together with wire rope. Timber piles can be protected from impact damage by banding the piles with sheet metal.

(2) *Steel tube.* Dolphin system is connected with bracing and fender arrangement.

(3) *Caisson.* Sheet-pile cylinders of large diameter filled with sand or concrete and topped with a concrete slab. Fendering can also be attached to the outside sheets, if needed.

*b. Fenders.* Fenders are designed to divert the flow of drift and ice around the piers. These fenders generally form a wedge on the upstream side of the pier to divert the flow.

(1) *Timber/steel bents.* A series of piles with timber wales and braces are attached to the top portion of the bent system. The steel piles may be tied together using a concrete slab (figure 3-19).

(2) *Steel or concrete frames.* Steel or concrete frames are sometimes cantilevered from the pier and faced with timber or rubber cushioning to reduce collision impact from surface craft and debris.

(3) *Timber grids.* Timber grids, consisting of post and wales, are attached directly to the pier (figure 3-19).

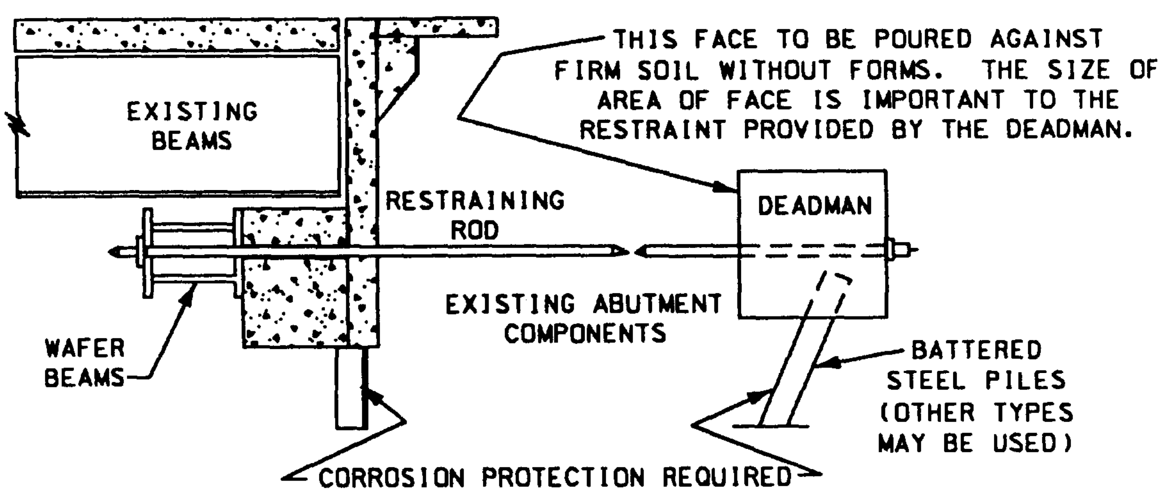



*Figure 10-2. Abutment held in place with a deadman.*

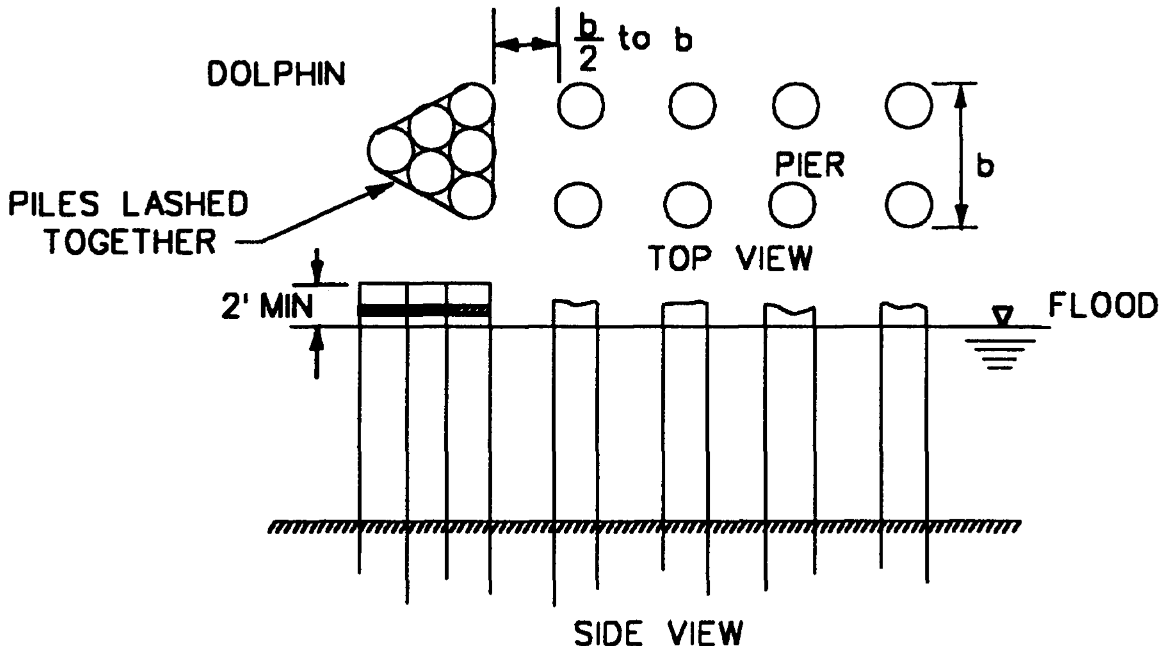



*Figure 10-3. Typical use of dolphins.*

## 10-18. Scour

When scour undermines the existing foundation, methods must be undertaken to reestablish the foundation. Scour can effectively reduce the bearing of piles, undermine pier footings and abutments, and cut into the bank.

*a. Piles.* When scour reduces the effective bearing of the piles in a pier:

(1) Additional piles can be added to the base of the pier to make up for the lost bearing and riprap added to prevent future scouring (figure 12-12).

(2) A concrete footing can be added to the base of the pier to make up for the lost bearing as follows (figure 10-4). Place a tremie encasement around the bottom of the pier. Inject concrete or mortar into the encasement. The concrete will displace the water from within the encasement. The formwork or encasement can be removed after the concrete is cured. Nails or spikes can be driven into timber piles, shear studs or bolts placed on steel piles, and rebar placed in drilled holes or the outer surface chipped on concrete piles to provide a better bond between the pile and the footing.

*b. Pier footings.* When footings are undermined, the most common repair method is to fill the void foundation area with a concrete grout or crushed stone. To place grout, some type of formwork must be used to confine the grout.

(1) *Concrete grout.*

*(a) Tremie encasement.* This is a steel, wood, or concrete form that is placed around the existing footing to reestablish the foundation. The form allows the concrete grout to be pumped under the eroded footing and displaces the water in the encasement through vents (figure 10-4).

*(b) Confinement walls.* Walls of stone, sandbags, or bags filled with riprap are placed along the faces of the footing and extending through the mud layer of the river bottom. The grout is injected into the cavity below the footing and the water is displaced through the voids in the wall. The grout penetrates into the voids in the wall and seals the confinement wall. The cavity is filled with grout and the foundation is reestablished (figure 10-5).

*(c) Flexible fabric.* A closed bag of canvas, nylon, etc., with grout injection ports is positioned under the footing. Grout is pumped into the bag and it expands to fill the cavity. The injection port is then closed and fabric confines the grout until it can cure (figure 10-5).

(2) Backfill.

*(a) Dry footing.* In this case the footing is not under water and may have been eroded by service runoff or flooding. A good structural fill material can be compacted into the erosion cavity to fill the void. If the streambed is eroded below the base of the footing, the compacted fill will be extended on a slope of 2 to 1 from the current streambed to the base of the footing. Riprap will then be placed around the footing to prevent further scouring.

*(b) Wet footing.* Crushed stone is used as the fill material (figure 10-6).

*c. Abutments.* Scour around the base of abutments can be repaired in a similar fashion as the pier footing as follows (figure 10-7):

(1) Shore up the abutment to prevent settlement during the repair,

(2) Remove any loose material from the scoured area,

(3) Set bolts into the abutment face along the length of the abutment. These bolts should extend 3 to 6 inches from the abutment face and be spaced 2 feet apart. Use the bolts installed in step 3 to connect an expansion shield to the abutment. Place concrete behind the shield to fill the erosion cavity and the space between the shield and abutment face. Place riprap on a 2 to 1 slope to prevent future scouring.

*d. Bank slope.* Erosion under and around a concrete slope protector can be repaired using a riprap till or may require extending the protector.

(1) *Riprap* (figure 10-8). Fill the scour hole with riprap. Extend the riprap above the face of the concrete to protect from future scouring. Slope the riprap level down from the edge of the protector to the face of the concrete protector.

(2) *Protector extension (figure 10-9).* Remove loose material from the scour hole. Backfill with sand or gravel. Form a ground mold in the backfill for the extended slope protector. Place concrete into the ground mold. Add the following steps for an undermine protector: cut a hole in the protector above the erosion cavity, backfill or grout through this hole, and repair the holes.

## 10-19. Settlement

Foundation settlement usually is caused by structural failure of the foundation material or scour.

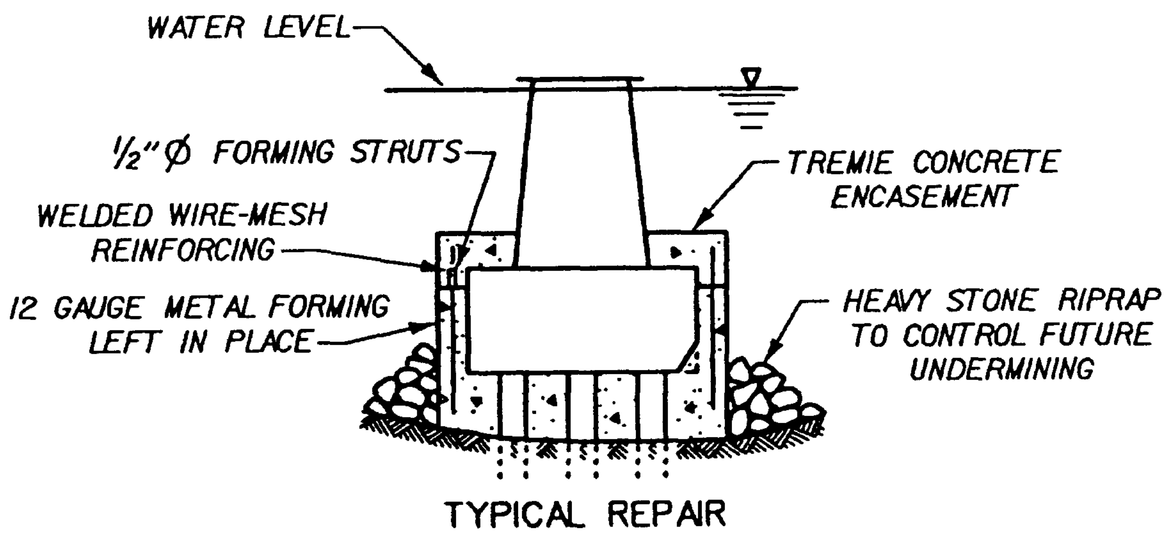



*Figure 10-4. Forming a footing with a tremie encasement.*

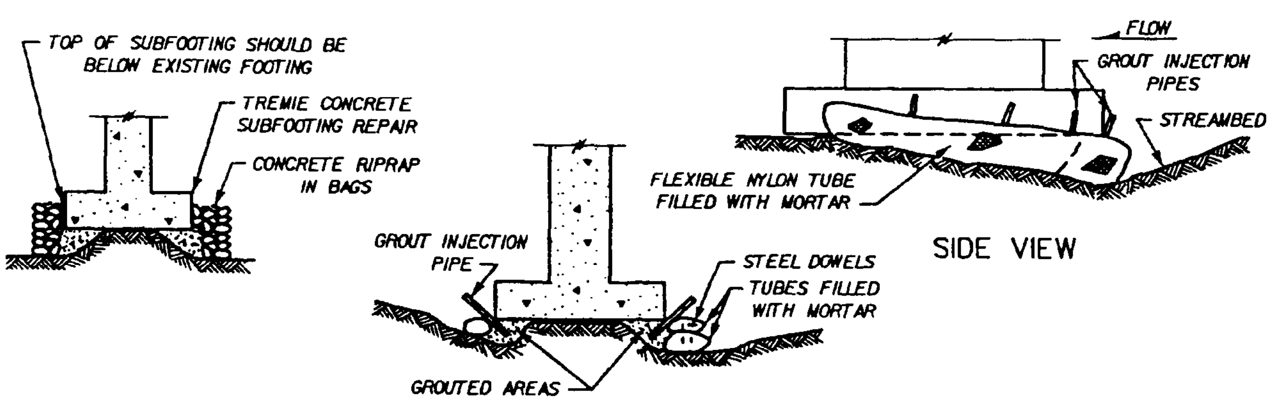
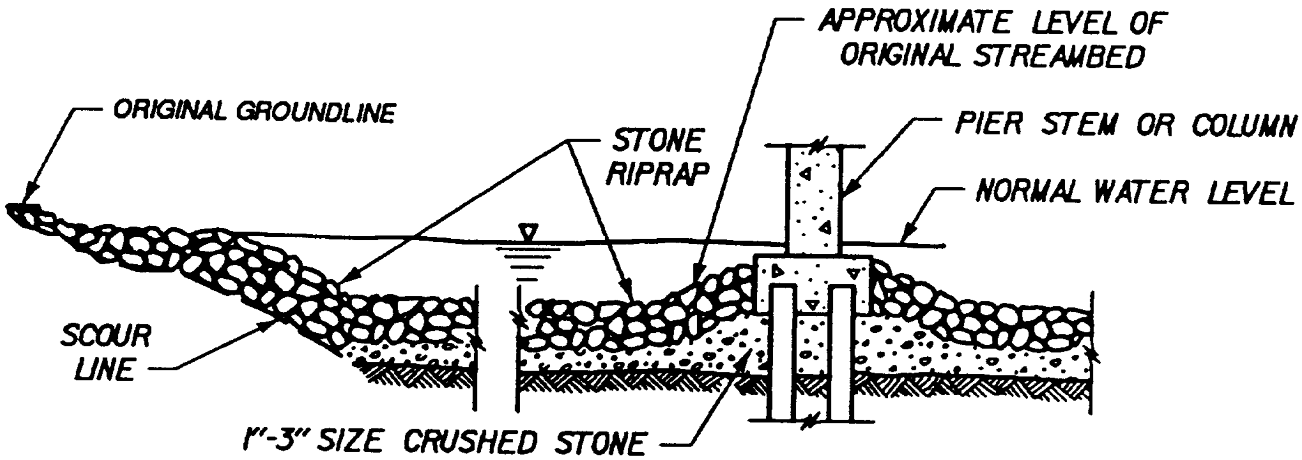



*Figure 10-5. Alternate methods for confining grout under footings.*




**NOTE: THE USE OF THIS SIZE CRUSHED STONE MAY BE PROHIBITIVE IF STREAM CURRENTS ARE STRONG**

*Figure 10-6. Use of crushed or structural fill to repair scour damage.*

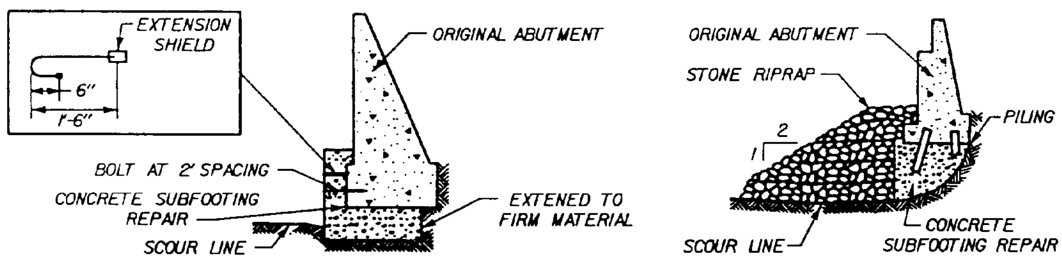



*Figure 10-7. Repair of scour around concrete abutments.*

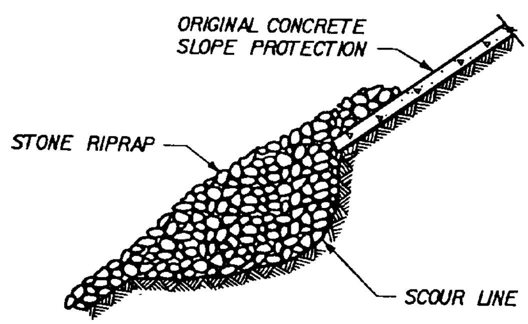



*Figure 10-8. Bank repair using riprap,*

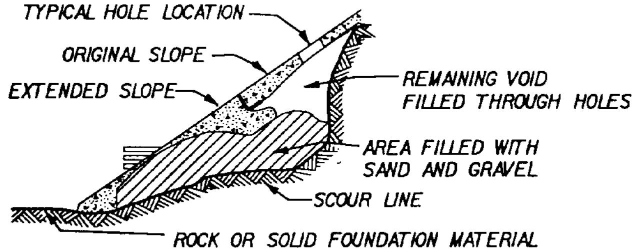



*Figure 10-9. Concrete bank protector extension.*

*a. Minor settlement.* This can be corrected by jacking up the structure and inserting steel shims between stringers and cap or between bearing plates and pedestal. Hard wood shims can be used under wooden members.

*b. Major settlement.* The pier is tilted or has settled to a point that it can no longer safely carry its design load.

(1) *Piles.* Correct the cause of the settlement by adding piles or a footing (Refer to related paragraphs in the following chapters for specific methods). Jack the deck to its proper position. Enlarge or replace the existing cap. Level the deck and remove jacks.

(2) *Pier footings.* Correct the cause of the settlement. Jack the deck to its proper position. Construct a level bearing surface for the superstructure. For bents, enlarge or replace the existing cap. For walls, enlarge the stem of the pier by placing a form around the stem and placing concrete. The concrete formwork should extend to the top of the pier to provide a level bearing surface (figure 10-10). Then cure, level the deck, and remove the jacks.

## 10-20. Waterway

Some waterways with flat gradients and flood plains have a tendency to shift channel locations. Such channel shifts may deposit eroded material: against the bridge piers, erode pier foundations, or attack the approach. This can be controlled by dikes of earth, rock, or brush mats.

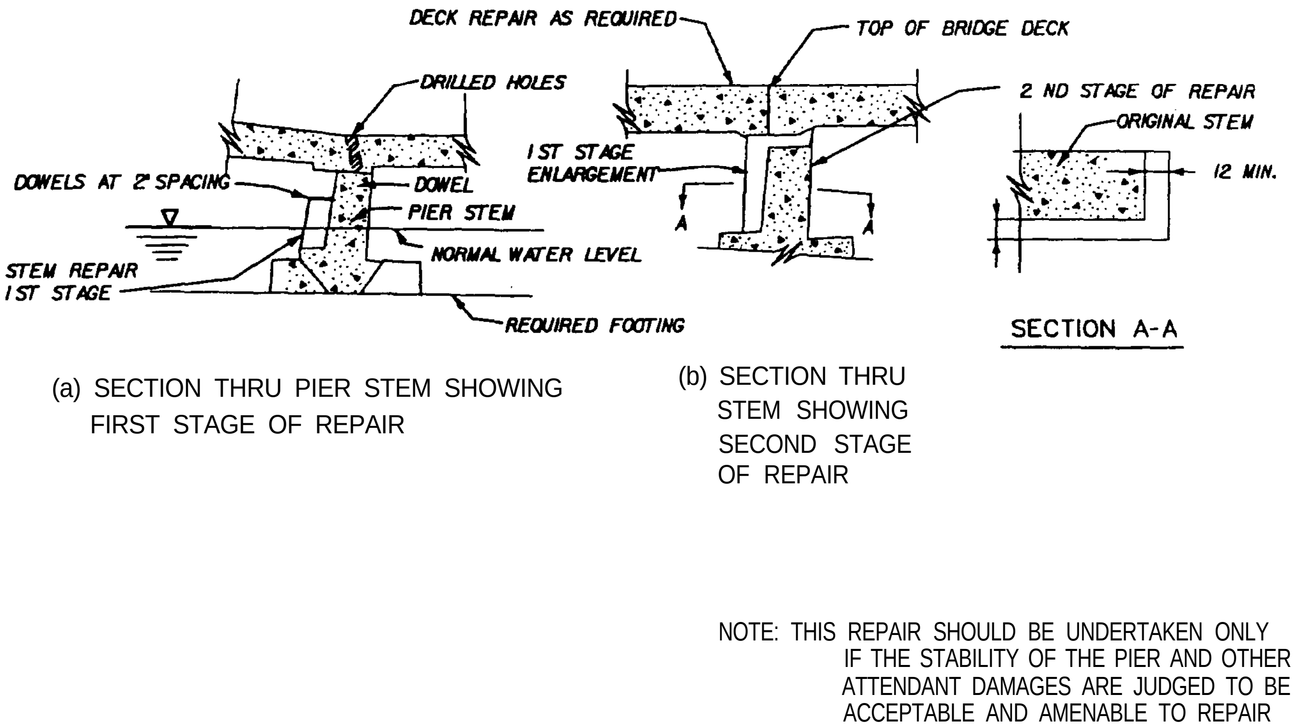



*Figure 10-10. Settlement repair of a concrete wall pier.*

# Section IV. COMMON METHODS TO UPGRADE EXISTING BRIDGES

## 10-21. General

There are several methods available to upgrade existing bridges. Some of the more common methods involve shortening the effective span length, adding stringers, strengthening the piers, reducing the dead load, and strengthening individual structural members. This section will discuss a few of the techniques involved with these upgrade methods.

## 10-22. Shortened span lengths

*a. Bearing point.* Shifting the bearing point can achieve a slight increase in bridge strength and can be used in conjunction with other upgrade methods to obtain a total bridge upgrade. The bearing point is shifted in toward the span, and the strength increase is limited by the size of the bearing surface on the abutment or pier cap. The shift can be accomplished by:

(1) Jacking the stringer off the bearing point and moving the existing point out on the bearing face.

(2) Placing a new bearing point in front of the existing point and using wedges to transfer the load to the new point.

*b. Intermediate piers.* The greatest bridge strength can be achieved by adding intermediate piers between the existing piers and abutments. The original span acts as a continuous beam and the negative movement must be checked over the intermediate pier.

*c. A-Frame.* For short spans, the A-frame provides an expedient substitute for installing an intermediate pier. The legs of the frame are anchored to the existing pier footings or footings are constructed for this purpose. These footings must be designed or reinforced to carry the lateral thrust transmitted through the frame's legs. The apex of the A-frame supports a cap which has a bearing surface for the bridge stringers. The use of the A-frame reduces the clearance below the bridge and may require additional horizontal reinforcement against seasonal floods (figure 10-11, part *a).*

*d. Knee-braces.* Knee-braces may be used to function in nearly the same manner as A-frames. However, the reaction of the span is not that of a continuous span and must be analyzed as support bracing (figure 10-11, part *b).*

### 10-23. Add stringers

The addition of stringers may require respacing existing stringers. The procedure increases the capacity of the existing deck and redistributes the loads carried by the stringers. When the deck is not replaced, special techniques must be used to place the new stringers. With the increase of the load carrying capacity of the superstructure, it is imperative to check the substructure for the same loading conditions.

### 10-24. Strengthen piers

*a. Add piles.* Drive additional piles and tie into the existing pier system.

*b. Add or increase* a *footing.* Once the footing is established, columns can be added between the new footing and the existing cap to provide a greater column strength in the pier.

*c. Add or enlarge columns.* The load carrying capacity of a pier or bent system can be increased by adding more columns or by adding material to the existing column cross sections.

### 10-25. Reduce deadload

The live load capacity of a bridge can be increased by reducing the applied dead load, thereby allowing existing capacity to be used for carrying increased live load. Significant dead load reductions can be obtained by removing an existing concrete deck and replacing it with a lighter deck. A reinforced concrete deck 8 inches thick weighs approximately 100 pounds per square foot. This weight is compared to the weights of lightweight decks in table 10-2.

### 10-26. Posttensioned bridge components

Posttensioning can be used to:

*a.* Relieve tension, shear, bending, and torsion overstress.

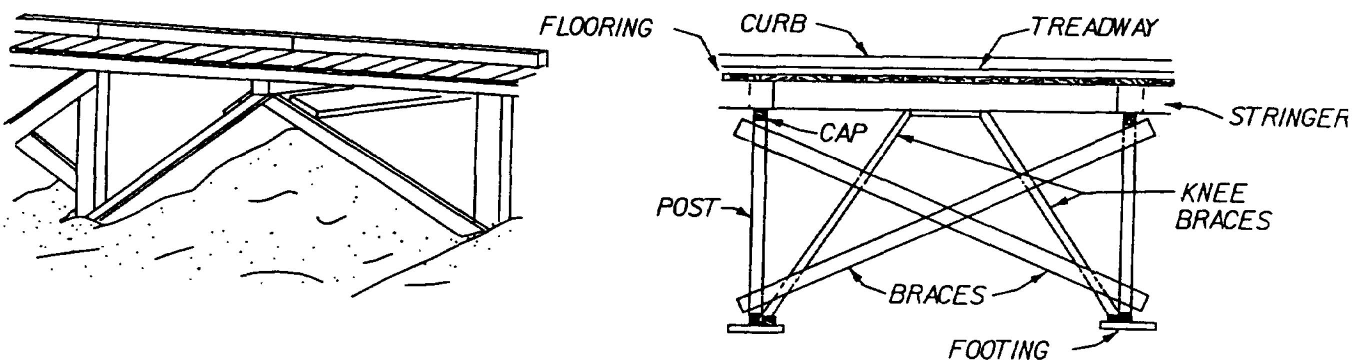
*b.* Add ultimate strength to the bridge structure.

*c.* Reverse displacements.

*d.* Change simple span to continuous span behavior. Various methods and configurations for posttensioning are shown in table 10-3.

### 10-27. Strengthen individual members

In many cases the bridge classification can be increased by strengthening the individual members of the structure. The drawbacks to this method are that it generally increases the dead load of the structure and the added material shall be considered effective in carrying the added dead load and live load only. Methods for strengthening individual members are dependent upon the material type and are thus discussed in the following chapters.




A. A-FRAME

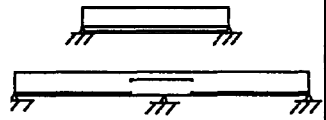
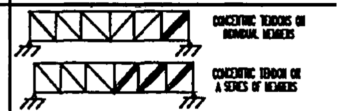
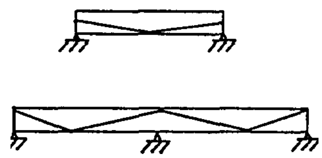
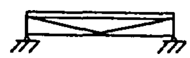
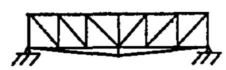
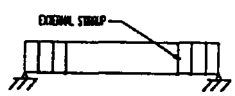
B. KNEE-BRACES

*Figure 10-11. Expedient methods of span length reduction.*

*Table 10-2. Lightweight decks*

| Lightweight Deck | Description | lb/sq ft |
|---|---|---|
| Open-grid steel deck | Steel stringers connected by a welded steel plate grid that provides the deck surface. Spans 5-9 feet. | 15-25 |
| Concrete-filled steel grid | Half-filled: S-inch deck with concrete placed in the top half of the grid.<br>Full-depth fill: S-inch deck with concrete placed full depth in the grid. | 46-51<br>76-81 |
| Exodermic deck | A 3-inch prefabricated concrete slab joined to a steel grating. Spans 16 feet. | 40-60 |
| Laminated Timber deck<br>Transverse Orientation | Vertically laminated 2-inch-diameter lumber bonded together into structral panels 48 in. wide with a depth from 3 l/8 *to 6* 3/4 in.<br>Longitudinal Orientation | 10.4-22.5 |
| Lightweight concrete deck | Concrete mix uses lightweight aggregate (expanded shale, slate, or clay). These decks can be cast in place or factory precast. | 75 |
| Orthotropic plate deck | Aluminum alloy plates with a skid-resistant polymer wear surface reinforced by extrusions. The deck bolts to the existing beams using hold-down brackets.<br>Steel plates - No standard design. | 20-25<br>45-130 |

*Table 10-3. Bridge posttensioning configurations*

| Method | Beam/Stringer Configuration | Truss Configuration |
|---|---|---|
| Eccentric Tendon<br>Includes axial compression and negative bending |  | |
| Concentric Tendon<br>Relieves tension members by applying axial compression. | |  |
| Polygonal Tendon<br>Induces axial compression, nonuniform negative bending in the posttensioned region, and shear opposite to load shear. |  |  |
| Polygonal Tendon with a Compression Strut<br>Similar to polygonal but doesn't add axial compression into the existing structure. |  |  |
| King Post<br>Combination of eccentric and polygonal tendon configurations. The moment to axial force ratio is large due to the king post.<br>Queen Post-uses 2 post. |  |  |
| External Stirrup<br>Timber - Sect. 13-7c(2)<br>Concrete - Sect. 14-72(1)<br>Box beam - Sect. 14-7e(2) | CONCRETE BEAMS<br> | BOX BEAMS<br> |

# CHAPTER 11

# STEEL BRIDGE MAINTENANCE, REPAIR, AND UPGRADE

## Section I. PREVENTIVE MAINTENANCE FOR CORROSION

### 11-1. General

Rust and corrosion are the greatest enemies of steel. When rust is allowed to progress without interruption, it may cause a disintegration and subsequently complete loss of strength in a bridge member. The corrosion also causes other problems such as pressure or friction between the surfaces.

### 11-2. Structural steel

Preventive maintenance of steel bridge components consists mainly of measures to protect the steel from corrosion. The preservation of steel involves protection from exposure to electrolytes, such as water or soil. When deicing salt is added to the electrolyte, there is a dramatic increase in the rate of corrosion of the structural steel. Corrosion is usually easily spotted by visual inspection. Protection from corrosion can take various forms:

*a. Weathering steel.* This special type of steel forms its own protective coating and theoretically does not need painting. However, many state highway departments have indicated poor performance from their bridges constructed with this type of steel. Therefore, members constructed from weathering steel should be monitored for excessive corrosion and painted if necessary.

*b. Paint.* Typical painting requirements are based on whether the steel is new or is to be repainted. The following steps are usually necessary:

(1) *New steel.* One prime coat applied in the shop, one prime coat applied in the field, two color coats applied in the field.

(2) *Repainting (depends on the condition of the existing paint).* If cleaned to bare metal, use one prime and two color coats. If cleaned to prime coat, use two color coats. If no prime exposed, use one color coat.

(3) *Paint seal.* The intersections and edges of metal surfaces can be protected from corrosion with a paint seal. This is a paste paint that prevents moisture penetration between the metal parts.

(4) *Notes.*

*(a)* When removing lead-based paint, precautions must be taken to protect against lead inhalation, ingestion, and pollution.

*(b)* Schedule field painting at the end of maintenance projects to avoid damage to the fresh paint.

*(c)* Separate cleaning and painting operations to avoid contaminating the fresh paint.

*(d)* Protect cleaned steel until paint can be applied.

*(e)* Apply paint to a dry surface that is not too hot. This ensures a good bond that does not blister (ambient temperature greater than 40 $^{o}$ F, relative humidity less than 85 percent).

*c. Cathodic protection.* Zinc or aluminum anodes are attached to H piles to abate corrosion of steel in salt or brackish water (figure 11-1). Small zinc anodes are used when less than 8 linear feet of pile is exposed. Large zinc or aluminum anodes are used when greater than 8 linear feet of the pile is exposed.

*d. Good housekeeping.* Steps to follow:

(1) Keep drains open to remove standing water from steel surfaces.

(2) Keep deck joints watertight to prevent water leakage onto steel members.

(3) Keep exposed areas clean by pressure washing.

(4) Spot paint and repaint as necessary.

(5) Maintain steel cables by removing foreign objects from the cable support system, cleaning and lubricating cable supports, tightening and replacing stirrups, and repairing cable wrapping.

## Section II. REPAIR AND STRENGTHEN

### 11-3. General

*a. Repair decision.* Each repair decision must carefully weigh the long-term operational requirements and existing environmental factors that can help accelerate corrosion prior to evaluating initial and life cycle costs. The physical condition of the structure must first be determined by a detailed inspection. The structural capacity of the steel should be known. Once the physical condition of the bridge is evaluated, a determination of

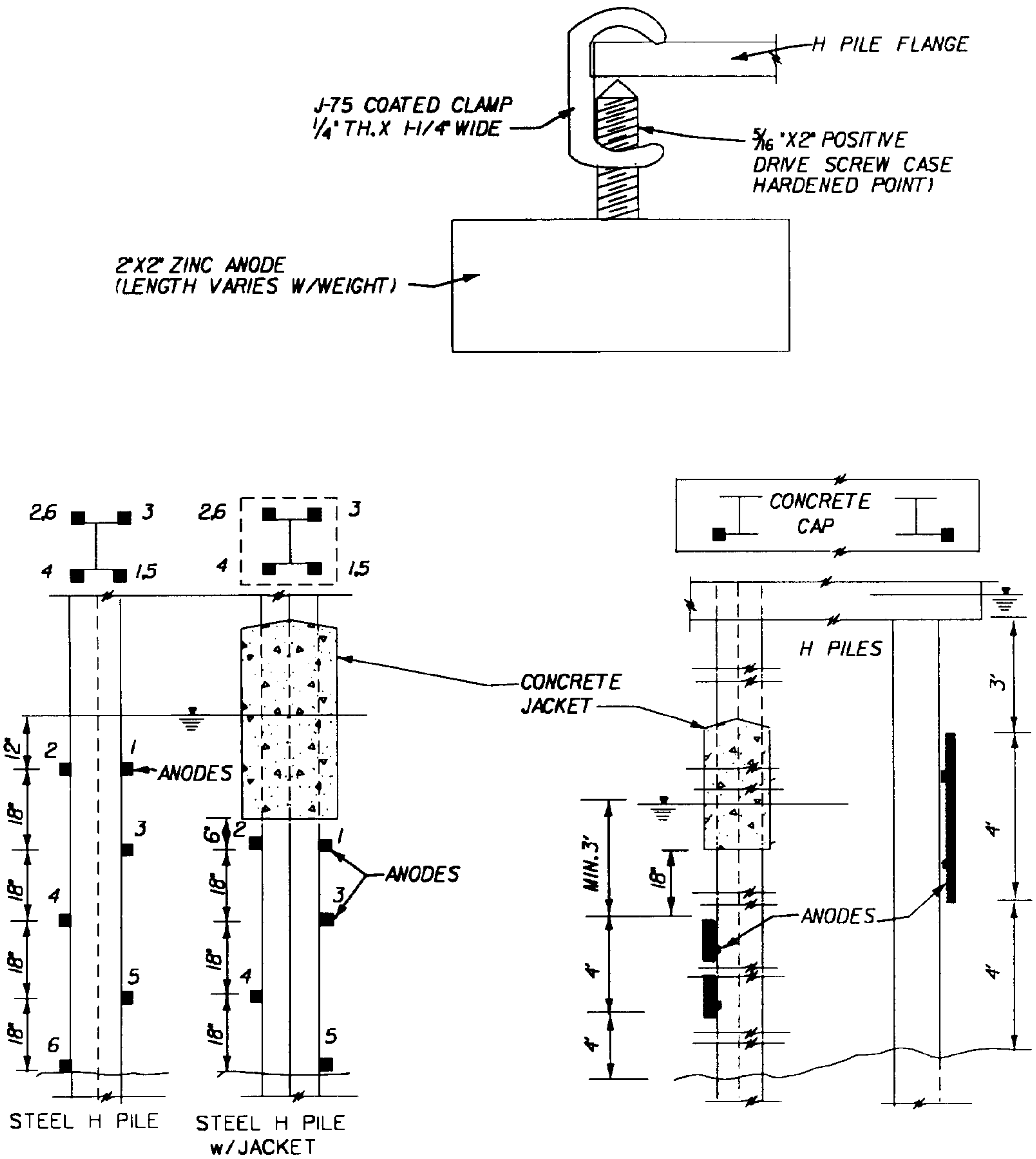



*Figure 11-1. Anodes placed on steel H piles for corrosion protection*

whether damaged bridge components should be repaired or replaced is made.

*b. Common repairs.* The most common steel repairs are:

(1) Adding metal to strengthen cross sections that have been reduced by corrosion or external forces.

(2) Welding or adding cover-plates to repair structural steel cracks caused by fatigue and vehicle loads.

(3) Retrofitting connections.

*c. Rules for adding steel.* When steel members are strengthened to carry a specified load, the permissible stresses in the added material must comply with the load design stresses. To properly analyze and design repairs that involve adding metal, the following rules are applied:

(1) Metal added to stringers, floorbeams, or girders shall be considered effective in carrying its portion of the live loads only.

(2) New metal added to trusses, viaducts, etc., shall be considered effective in carrying its portion of the live load only. The exception is when: The dead load stress is temporarily removed from these members until the new metal is applied, or the dead load stress is applied to the new metal when it is applied.

(3) The added material shall be applied to produce a balanced section, thus eliminating or minimizing the effect of eccentricity on the strengthened member. Where balanced sections cannot be obtained economically, the eccentricity

of the member shall be taken into account in determining the stresses.

(4) Strengthened members shall be investigated for any decrease in strength resulting from temporary removal of rivets, cover plates, or other parts. In some cases falsework or temporary members may be required. Where compression members are being reinforced, lacing bars or tie plates shall be replaced before allowing traffic over the bridge.

## 11-4. Connections

Primary connections involve the use of welds, bolts, or rivets. However, pin connections and threaded fasteners are used commonly in tension members.

*a. Welds.* Electric arc welding may be employed subject to the approval of the engineer. In general, welding can be used to repair broken or cracked welds, strengthen rivet connections, and add metal to existing steel members.

(1) *Broken or cracked welds.* Remove all dirt, rust, and paint for a distance of 2 inches from the damaged weld. File or grind down the damaged weld to ensure the weld will bond with the steel surfaces being welded together. For cracks, grind down the cracked weld until the crack is no longer visible then check the weld with dye penetrant to ensure the crack has been completely ground out. Replace the weld. Apply paint or a corrosion protector to welded area.

(2) *Welded rivet connections.* Remove all dirt, rust, and paint for a distance of 2 inches from the steel surfaces in which the weld is to be applied. Apply welds to join the steel surfaces. Where overstressed rivets/bolts can carry the dead load, the weld is designed to carry the impact and live loads. Where overstressed rivets/bolts cannot carry the dead load, the weld is designed to carry the total load. Apply paint or a corrosion protector to welded area.

(3) *Added metal for strength.* Clean the steel surfaces in which metal is to be added and remove any severely damaged or corroded steel portions. Use welds to fill cracks and holes, to replace removed steel portions, or to add coverplates to strengthen individual members. With cracks, ensure the weld penetrates the full depth of the crack. With holes, work the weld from the steel surface to the center of the hole ensuring no voids are allowed in the weld. Replace removed steel portions with steel of the same strength, and, if a torch is used to cut the steel, ensure the edges are ground smooth to ensure a good welding surface. When adding coverplates that will be subjected to compression, ensure the maximum clear spacing distance (d) is less than 4,000 multiplied by t divided by Fy, where t = plate thickness in inches and Fy = yield stress in pounds per square inch. This prevents local buckling of the attached plate when loaded in compression (figure 11-2). Apply paint or a corrosion protector to welded area and added steel.

*b. Rivets.* Riveted connections can be repaired using many different methods. The most common repair requirements are for loose or missing rivets or an understrength connection. The repair techniques for each are as follows:

(1) *Loose or missing rivets.* Clean working surface. Replace all missing rivets with high-strength bolts of the same size and draw the nut up tight. This will help support the connection during the repair operations. Tighten or remove and replace loose rivets with high-strength bolts or new rivets. Work on only one rivet at a time to help maintain the proper load distribution to the rivets. Remove and replace high-strength bolts with rivets, one at a time, if the engineer requires rivets for the repair work (high-strength bolts can be substituted for rivets). Check all bolts and/or rivets to ensure tightness. Apply paint or corrosion protector.

(2) *Understrength connection.* Several options exist for an understrength connection:

*(a)* Rivets or bolts can be added to the existing connection plate.

*(b)* A longer connection plate can be added to allow for more rivets.

*(c)* Larger rivets or bolts can be substituted for the existing ones.

*(d)* Welds can be added to the connection plate of sufficient strength to carry impact and live loads or the total load depending on the condition of the connection.

*c. Pin connection.* The pin connections discussed herein refer to those used in tension members and military assault bridges. The repair of such con-

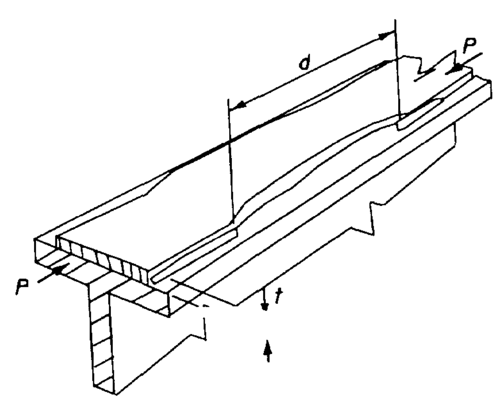



*Figure 11-2. Local buckling under compression.*

nections may involve the pin itself or the pin housing. To repair or replace the pin or housing, the load must be shifted from the connection through use of jacks or winches. The pin can then be removed from the housing. Repair the housing using welds or by adding metal to build up the connection, as necessary. The pin can either be replaced or a bolt of the same size can be used. The pin connection should be replaced with a welded or riveted connection if it is functioning as a fixed connection or if the bridge is considered a permanent structure.

*d. Threaded fastener.* Threaded fasteners are used primarily in conjunction with a tension rod or cable. Typical problems with these fasteners involve stripped threads, a rust frozen shaft, or a broken threaded shaft.

(1) *Stripped threads.* Remove the threaded shaft and rethread if necessary. Drill out the threads in the female housing. Place the rethreaded shaft through the female housing and retighten the fastener with a bolt on the backside of the housing.

(2) *Rust frozen shaft.* Clean the shaft and housing of external rust and apply a lubricant to the threads. Attempt to rotate the shaft; if the shaft still refuses to rotate, the fastener must be replaced. Cut the threaded portion of the shaft from the tension member and splice a new threaded shaft to the member. Remove the frozen portion of the shaft from the housing using a torch. Place a bolt on the backside of the housing and pull the tension member tight.

(3) *Broken shaft.* Splice the shaft as shown in figure 11-3.

## 11-5. Repair of structural members

Structural steel members are generally classified by the function they perform. The primary members are tension members, compression members, beams, and beam-columns. The repair of various structural members is discussed in the following paragraphs.

*a. Bars.* Structural bars can be either round or rectangular and have a pin or threaded connection. Repair of the bar itself involves tightening the bar to account for elongation, adding metal to the eye of a pin connection, or splicing the bar to repair breakage.

(1) *Tightening adjustable connections or turnbuckles.* Clean the components and attempt to tighten the bar. If adjustments cannot be made, adjustments can be made to the eyes or turnbuckles can be added as follows:

*(a) Adjustments to the* eyes. For slack of less than 1 inch, the pin connection can be shimmed to take up any slack between the pin and the eye of the bar. Shimming is accomplished by removing the pin from the housing and placing a metal sleeve snugly around the pin and the inside of the eye of the bar. The metal sleeve will take up the slack between the pin and the eye of the bar.

*(b) Add turnbuckle.* A turnbuckle can be added to a round bar which previously had no adjustable tension system (figure 11-3). This is accomplished by cutting a section out of the existing bar, threading both adjacent ends of the cut, and screwing on a turnbuckle.

(2) *Broken/damaged bars.* Repair broken or damaged bars as follows:

*(a) Add turnbuckle.* Cut out the damaged area and use the same technique discussed in paragraph 11-5a(1)(b) above.

*(b) Splice bars.* Broken bars can be spliced by welding bars or plates on both sides of the damaged area as shown in figure 11-3. Bolts and rivets can also be used if desired.

(3) *Reinforcement of eyebars with loop bars.* Eyebars can be reinforced with loop bars in the following manner. Release tension from the eye or consider the added metal for carrying live load and impact loading only. Weld a plate onto the existing eyebar. This plate can be used to attach a supplemental eye (loop or forged bar which reinforces the eye of the bar). Place loop bars around the pin and weld to the steel plate (figure 11-4, part a). Reapply tension and paint repaired area.

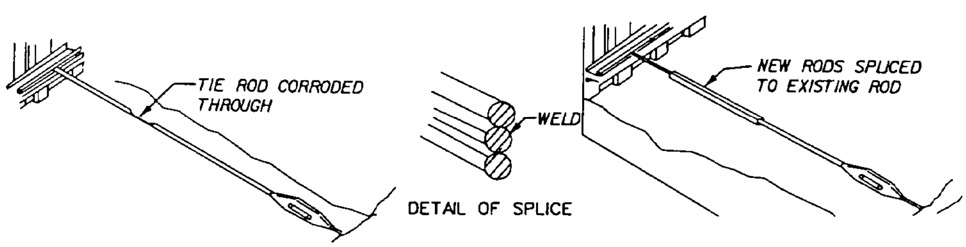
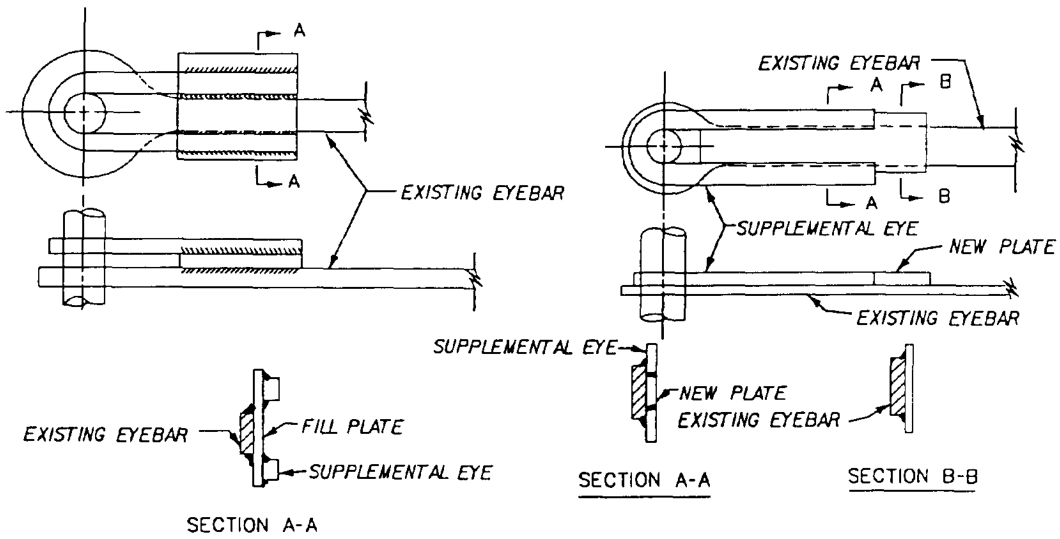



*Figure 11-3. Repairing tie rods with splices or turnbuckles.*




A. USING A FILL PLATE B. USING A CUT PLATE TO REDUCE WIDTH

*Figure 11-4. Strengthening pin connections using a supplementary eye.*

(4) *Reinforcement of eyebars with steel plates (figure 11-4, part b).* Eyebars can be reinforced with steel plates by the following procedure. Release tension from the eye. Place a supplemental eye around the existing eyebar. Slide a new plate between the arms of the supplemental eye. The thickness of the new plate should be equal to that of the supplemental eye. Its width should be equal to the diameter of the pin for the approximate length of the arms of the supplemental eye, and then it should widen to a width greater than the existing eyebar. Its length should be determined by the load carrying capacity requirements of the welds. Weld the supplemental eye, new plate, and eyebar together. Replace the pin, reapply tension, and paint the repair.

*b. Hanger plates.* Pin and hanger connections are especially vulnerable to corrosion, which may freeze the connection and increase the internal stresses in the hanger, causing cracks to form. If the hanger must be removed for cleaning or repair, a technique which can be used is:

(1) Fashion a temporary hanger to support the dead load normally carried by the hanger. This can be accomplished as follows:

*(a)* Place a steel plate across the expansion dam on the road surface. The plate should have two holes running the length of the dam and at a distance slightly greater than the flange width of the girder apart.

*(b)* Run two threaded bars capped with nuts through the holes to the bottom of the girder's bottom flange.

*(c)* Attach a plate to the bars below the bottom flange.

*(d)* Tighten the nuts on the top plate to draw the bottom plate up tight to the bottom flange and adjust the tension on the hanger.

(2) Once the temporary hanger is in place, the connection can be cleaned and repaired as follows:

*(a)* Attach a safety cable to the outside hanger and remove the hanger from the pins.

*(b)* Clean the pins and hanger thoroughly and repair any damage to these components.

*(c)* Spot paint the inside face of the hanger with light layers of paint and allow time for the paint to dry while working on the pins.

*(d)* Lubricate the pins and replace the hanger.

*(e)* Repaint the outside face of the hanger.

*(f)* Repeat the procedure for the inside hanger.

(3) Remove the temporary hanger.

*c. Cable.* The most common damage that occurs to cable is fraying of the steel wires forming the cable. Any repair requiring strengthening the damaged portion of the cable involves removing the tension on the cable. There are three repair techniques that can be used on damaged cables.

(1) If the cable still retains adequate strength to carry its design loading despite the frayed area, then clip off the frayed wires, clean any rust and debris from the cable, and paint or wrap the damaged portion of the cable with a protective coating.

(2) If the cable requires strengthening, then replace the cable, run an additional cable parallel

to the existing cable to carry the balance of the load, or cut the cable and emplace a turnbuckle.

*d. Rolled sections or plate girders.* The most common repairs to these sections are repairing cracks in welds and strengthening the sections with cover plates. In some cases, bent steel sections are repaired using a technique called structural steel flame straightening.

(1) *Crack repair.* The typical cracks that occur in rolled sections and plate girders are caused by fatigue and overloading. The cracks generally begin in the flange and propagate through the flange into the web. To properly repair these cracks, the cracks must first be closed and then a weld applied. The importance of closing the crack is to ensure that the dead load is properly transferred across the entire cross section of the steel member. There are various methods which can be used to close these cracks:

*(a)* Posttensioning the member (see paragraph 11-10).

*(b)* Jacking the load off the member (see paragraph 12-7).

*(c)* Using a heated cover plate across the crack and following these steps. Weld a cover plate to the member along only one side of the crack. Heat the cover plate to expand the plate's length. While still heated, weld the opposite side of the plate to the member and allow the plate to cool and contract. This will pull the crack together. Weld the crack and apply a continuous fillet to the cover plate.

(2) *Cover plates.* The cover plate is a relatively easy and inexpensive technique to use in steel repair. It can be used to bridge over a crack and transfer the dead load throughout the cross section of the steel member or to just add strength to the member's cross section. A key dilemma when adding steel cover plates is the method used to introduce dead load stresses into the new material. The most common method used with major members (i.e., W-sections) is to calculate the amount of shorting required to produce the dead-load stresses in the existing member. Holes are drilled into the old and new members in such a way that the new members will be shortened by drifting, as the sections are bolted together. Another method is heating the cover plate after welding one end and then welding the expanded plate into place as discussed. As the plate cools and contracts, stresses will be added to the cover plate. Examples of various uses of the cover plate are:

*(a)* Extending an existing cover plate to bridge a welded crack (Refer to paragraph 11-4a(3)).

*(b)* Building up the bottom flange, top flange, or the web of the member to increase the load capacity of a steel member.

*(c)* Bridging or strengthening steel sections damaged by corrosion or collisions (figure 11-5).

(3) *Rules for using cover plates.*

*(a)* When one or more cover plates must be renewed, consideration must be made for replacing the defective plates with one plate of adequate size.

*(b)* Cover plates should be connected by continuous fillet welds, high-strength bolts, or rivets.

*(c)* Where the exposed surface of old plates are rough or uneven from corrosion and wear, they should be replaced with new plates.

*(d)* Welded cover plates should be of sufficient thickness to prevent buckling without intermediate fasteners.

*(e)* Where the web was not originally spliced to resist moment, it may be spliced by adding cover plates or side plates.

*(f)* Where fatigue cracking can occur at the top of welds on the ends of the cover plate, it is recommended that bolting be used at the cover plate ends.

*(g)* When cover plates are used in compression members, care must be taken to maintain symmetry of the section to avoid eccentrical loadings.

(4) *Alternative to cover plates.* Where the cost of removal and replacement of the deck would be excessive, as in ballasted-deck bridges, flange sections may be increased by adding full-length longitudinal angles, plates, or channels just below the flange angles. First remove the stiffener angles and then replace them with new stiffeners after the flange steel is added (figure 11-6).

(5) *Stiffeners.* Stiffeners are used to reinforce areas of the beam which are suspectable to web buckling (intermediate transverse stiffeners), concentrated loads greater than allowable stresses (bearing stiffeners), and web buckling due to bending (longitudinal stiffeners).

*(a) Intermediate stiffeners.* Additional stiffeners may be added by riveting, high-strength bolting, or welding angles or metal plates perpendicular to the top flange and web. These stiffeners should not be connected to the tension flange of the member.

*(b) Bearing stiffeners.* These stiffeners can be reinforced by adding angles or plates to the existing stiffeners, grinding the bearing ends of the new parts to make them fit closely, or welding the bearing ends to the flanges.

*(c) Longitudinal stiffeners.* Stiffness may be added to the member by bolting or welding longi-

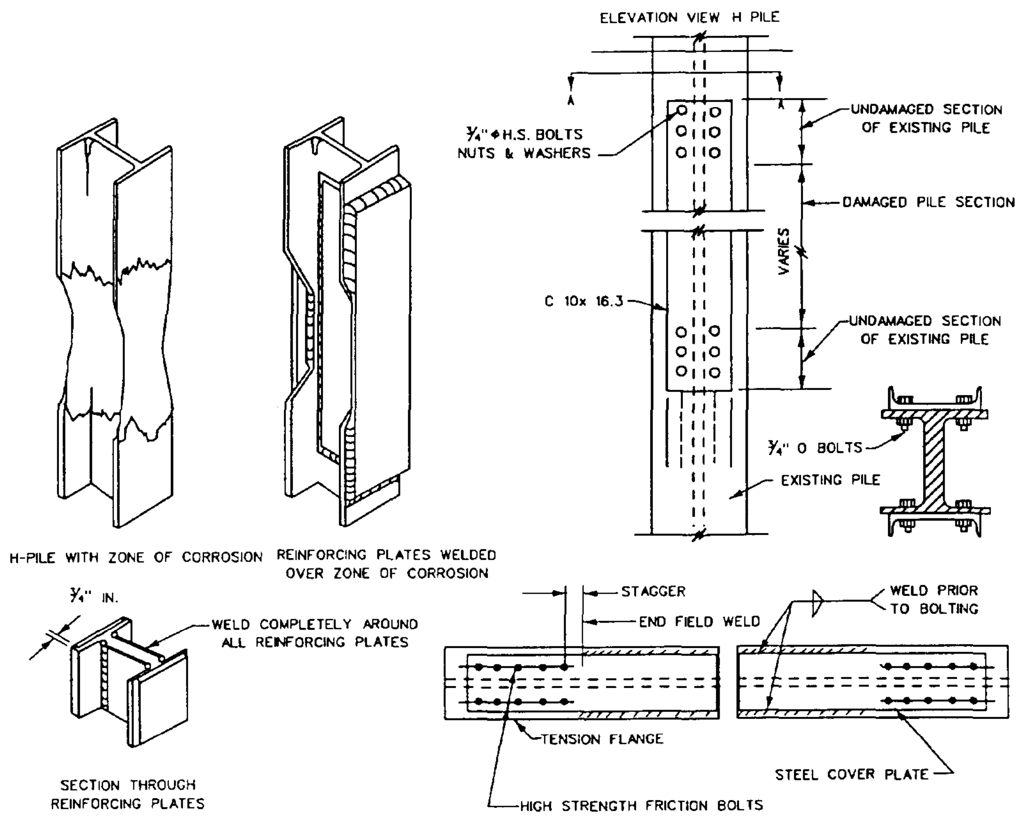



*Figure 11-5. Use of cover plates on rolled steel sections.*

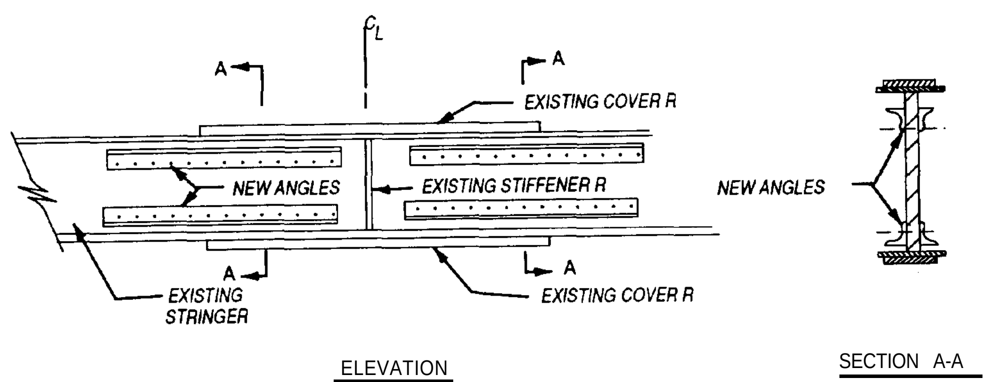



*Figure 11-6. Iowa DOT method of adding angles to steel I-Beams.*

tudinal angles to the web of the steel member.

(6) *Piles.*

*(a)* When steel piles require additional support or protection, an integral pile jacket can be placed around the steel piling. The encasement of the steel piles is accomplished by filling a fiberglass form with Portland-cement grout. After the concrete hardens, the fiberglass form remains in place as part of the jacket. The integral jacket provides protection to steel piles above and below the water. If the pile has deteriorated to the point that additional steel support is required, cover plates can be added to the pile prior to placing the jacket or a reinforced concrete jacket can be designed.

*(b)* A procedure for installing an integral pile jacket follows (figure 11-7). Sandblast the surfaces clean of oil, grease, dirt, and corrosion (near white metal). Place the pile jacket form around the pile. Ensure standoffs are attached to the form. Seal all joints with an epoxy bonding compound and seal the bottom of the form to the pile. Brace and band the exterior of the form to

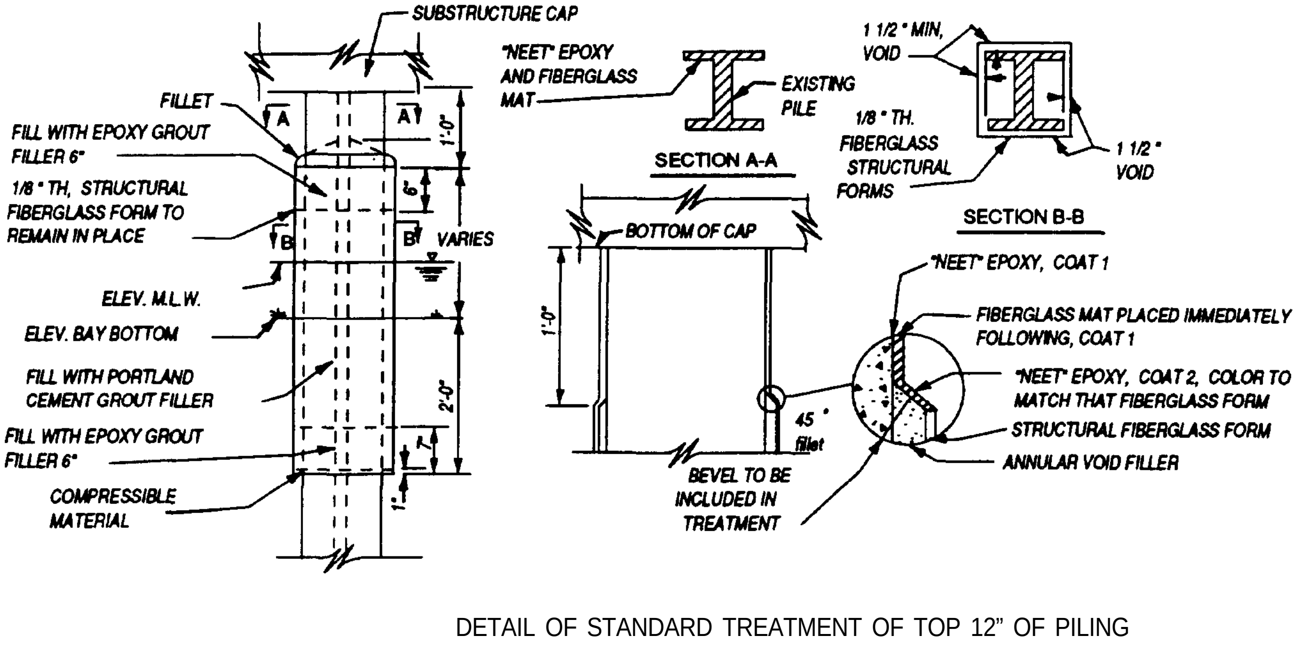



*Figure 11-7. Integral pile jacket for steel piles.*

hold the form in place. Dewater the form. Fill the bottom 6 inches of the form with epoxy grout filler. Fill the form to within 6 inches of the top with a Portland-cement grout filler. Cap the form with a 6-inch fill of epoxy grout. Slope the cap to allow water to run off. Remove the external bracing and banding and clean off the form of any deposited material.

(7) *Flame straightening.* Flame straightening has been used for over 40 years to straighten bent beams or align members for proper connections. This process involves using "V" heats or triangle heats on flanges in conjunction with jacking devices to shrink the beam in the desired direction. The "V" heat is not heated completely, nor is it gone over again until cooled. The base of the "V" heat should not exceed 6 inches to avoid warping of the flange. The heat used in the process should not exceed 1,200 $^{o}$ F and in most areas will probably be less. It is usually necessary to heat the webs of damaged beams in conjunction with the flange. Overheating and jacking can cause the flange to exceed its yield strength and move vertically, instead of the desired horizontal direction. For these reasons, this process should be conducted with trained and qualified operators only to direct and monitor all heats, jack placements, and to supervise the program's sequence of events.

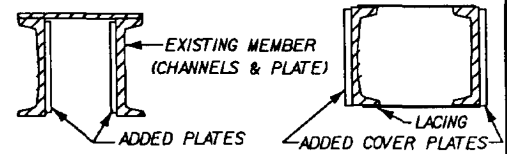
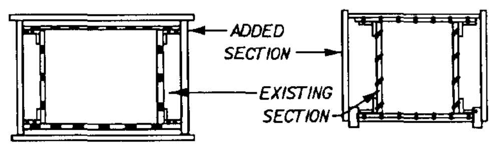
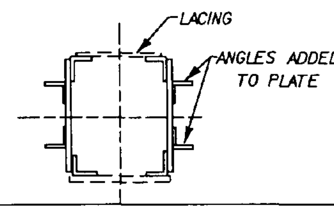
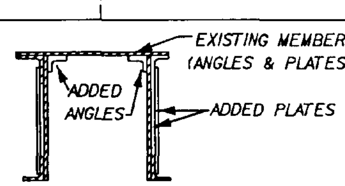
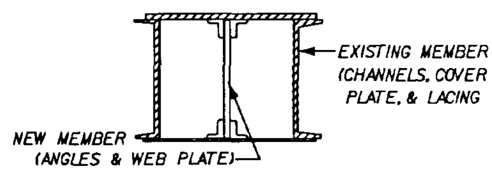
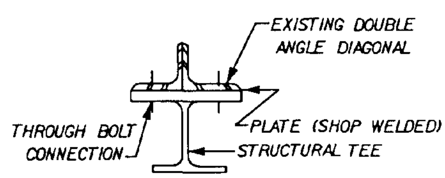
*e. Built-up sections.* These sections are primarily used to form truss systems. Cracks due to fatigue and overloading are repaired in the same manner as rolled sections discussed previously. A combination of cover plates, plates, angles, and other rolled sections can be used to reinforce or strengthen the built-up member. Adding metal to these sections increases the cross-sectional steel area in tension members, reduces the slenderness ratio in compression members, and increases the sectional modulus in beams. Examples of strengthened members are shown in table 11-1.

*f. Composite sections.* Composite action is developed when two load-carrying structural members such as a concrete deck and the supporting steel beams are integrally connected and deflect as a single unit. To ensure that no relative slippage occurs between the slab and beam, the beam's flange is imbedded into the concrete or shear connectors are used to develop a composite action between the surfaces. Three areas may require repair on a composite bridge: the concrete deck, the steel beam, or the composite action between the deck and beam.

(1) *Concrete deck.* Concrete deck damage or faults can decrease the bridge's load capacity by reducing the composite action of the section. The concrete maintenance and repair techniques discussed in chapter 13 should ensure that the deck will carry the compressive forces required by the composite action.

(2) *Steel beam.* Any cracks or damage to the steel section should be repaired (paragraph 11-5d(1)) to ensure that, the correct composite action is received.

*Table 11-1. Built-up members*

| ADDED METAL | DESCRIPTION | FIGURE |
|---|---|---|
| COVER PLATE/ PLATES | COVER PLATE IS WELDED TO THE COMPRESSION MEMBER TO INCREASE THE STEEL AREA AND REDUCE THE SLENDERNESS RATIO |   |
| | END POST AND BOTTOM CHORDS OF A THROUGH TRUSS ARE BOXED IN WITH STEEL PLATES. |   |
| ANGLES | ANGLES ARE ADDED TO THE MAIN EXISTING PLATES FOR ADDED STRENGHT. |   |
| ANGLES & PLATES | PLATES AND ANGLES ARE ADDED TO AN EXISTING MEMBER TO REDUCE THE SLENDERNESS RATIO. |   |
| | PLATES AND ANGLES ARE ADDED TO PROVIDE A CENTRAL WEB IN AN EXISTING COMPRESSION MEMBER. |   |
| ROLLED STEEL | A PLATE/TEE SECTION OR A I, W SECTION IS USED TO INCREASE THE STEEL AREA IN A TENSION MEMBER. |   |

(3) *Composite action*. Several repair techniques exist to address the loss of composite action:

*(a) Allow for noncomposite action*. Build up the steel beam to carry the load neglecting composite action. Angles can be added to the bottom of the top flange, cover plates can be added to the bottom flange, and/or stiffeners can be used to offset web buckling.

*(b) Repair shear connectors*. The composite action of the section can be reactivated by repairing the shear connectors in the following manner. Use bridge diagrams and plans to determine the location and type of the shear connectors. Remove the concrete from around the shear connector. Repair the existing connectors or replace with welded studs. If welding is not feasible, high-strength bolts can be used as the shear stud as demonstrated in figure 11-8. High-strength bolts may also be added to increase the composite action.

*(c) Deck replacement*. The deck can be completely replaced to renew the bond between the concrete and the shear connectors. A new deck can be poured or a new precast deck can be emplaced with holes cast for the connectors, using grout in the holes around the connectors (paragraph 11-9). Note that the composite action is normally de-

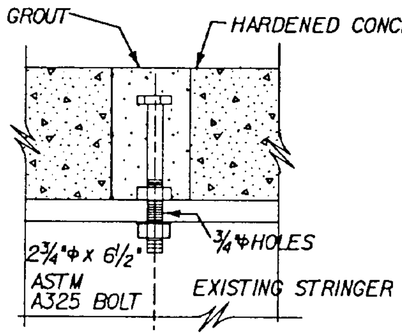



*Figure 11-8. Details of double-nutted bolt shear connector.*

signed for live and impact loading, unless the dead load is distributed during the concrete curing process.

*g. Steel grid decks.* Steel decks are often used to increase the live load capacity of bridges when used to replace concrete decks. The primary maintenance and repair problems with steel decks are deterioration from exposure to the weather, weld failure, and skid resistance. Repairs for corrosion and welds are the same for steel decking as with any other structural steel member.

(1) *Concrete fill.* Another method of repair commonly used is to fill or partially fill the steel grid with concrete. The concrete filled grid acts as a reinforced concrete deck. The steel grid provides the steel reinforcement and the concrete fill provides stiffness to help carry the load. This repair technique has several advantages: increased deck strength, reduction in the effect of weathering by limiting the water penetration, support of the welded grid joints, and increased skid resistance. A wearing surface can be added to the deck to provide additional skid and weather resistance. Recommended wearing surfaces are: latex modified concrete (l-inch thickness), asphalt (1.75inch thickness), concrete overfill (1.75inch thickness), or epoxy asphalt (5/8-inch thickness).

(2) *Exodermic deck.*

*(a)* This deck consists of a thin upper layer (3-inch minimum) of precast reinforced concrete deck panels joined to the steel grating. The panels can be precast and placed on a bridge or added to an existing steel deck using shear connectors welded to the steel grid.

*(b)* The emplacement procedure follows. Weld shear studs/connectors to the steel grid. Precast concrete deck panels with holes for the shear studs. Place a thin metal, wood, or cardboard plate with a diameter greater than the precast stud hole around the stud. Place the precast concrete deck panels on the steel grid and grout the stud holes. Seal the cracks between the concrete panels.

## Section III. MEMBER REPLACEMENT

### 11-6. Tension members

Any tension in the member must be transferred to a temporary cable support system prior to removing the damaged member (figure 11-9). Attach a cable/turnbuckle system to the supporting frame parallel to the member to be replaced. Transfer the load carried by the steel member to the cable by tightening the turnbuckle. Remove and replace the damaged steel member. Remove the temporary cable support system.

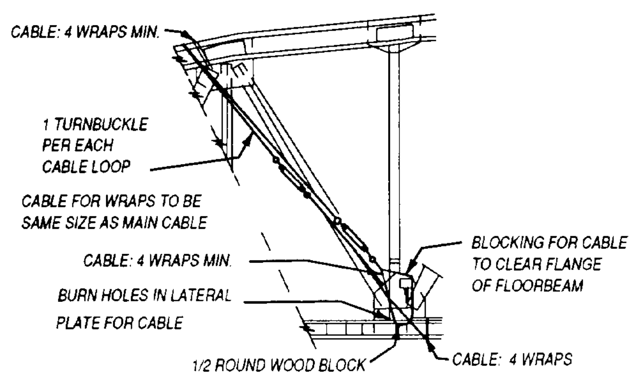



*Figure 11-9. Method for relieving stress in tension members.*

### 11-7. Compression members/columns

The primary method to support the compressive load during replacement is block and bracing. Emplace a steel or wood section parallel to the member to be removed. Jack the load off the damaged member and place wood or steel shims on the temporary support to transfer the load to the temporary support. In some cases the shims may be driven between the temporary support and the frame to transfer the load. A cable support system wrapped around the temporary support and the frame can be used to hold the member in place during the replacement operation. Remove and replace the damaged compression member. Remove the shims and temporary support.

### 11-8. Beams

The addition or replacement of a stringer is normally performed in conjunction with the replacement of the deck. If the deck is not removed the member must be replaced. from under the bridge. The beam replacement method will depend upon whether the beam/deck system is composite or noncomposite.

*a. Noncomposite beams.* Place jacks under the deck or under the beams that are not being replaced and jack the deck off the beam to be removed. Remove beam or repair the damaged end of the beam. The beam may be cut to facilitate removal. The beam may be jacked out of position or a lift truck used to lower the beam. Lift or jack the replacement beam into place. To use a lift truck or cable system, a hole must be cut or drilled into the deck to run the cable through. Position the beam on the bearing plates, jack the deck down onto the new beam and check for distress in the beam and deck. Remove jacks, temporary supports, and repair any holes in the deck.

*b. Composite beams (figure 11-10).* Use jacks to lift the composite beam off its bearing. Burn or cut the lower portion of the beam (web and bottom flange) from the fixed top flange. Grind the cut area of the top flange smooth. Weld a new stringer to the old stringer top flange for continuity.

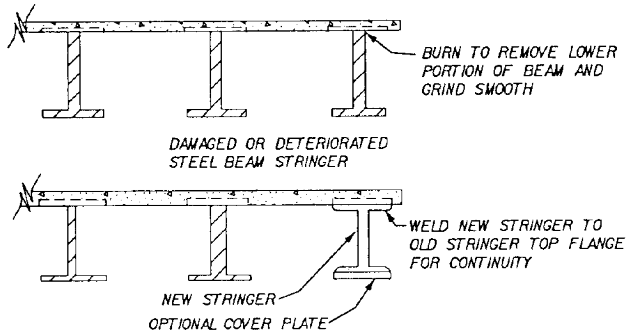



*Figure 11-10. Replacement of a steel beam in a composite section.*

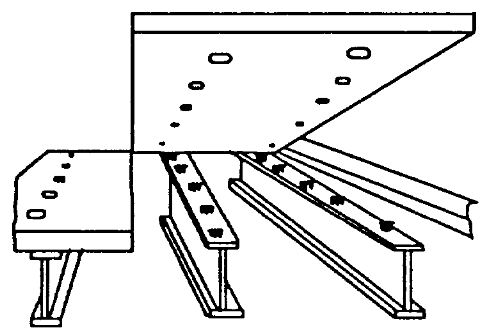
## Section IV. UPGRADE STEEL BRIDGES

### 11-9. Creation of a composite action

The overall strength of a noncomposite stringer/ deck configuration can be greatly increased by making the deck and stringers work together as a single unit using composite action.

*a. Concrete deck.* The condition of the deck determines how to obtain composite action between the deck and the stringers. If the concrete deck does not need replacing, create a composite action between the deck and stringers by the introduction of shear connectors or studs across the interface of the two materials. If the deck is badly deteriorated, remove the deck and emplace shear connectors or high strength bolts as discussed in section II of this chapter. Another alternative to recasting the deck is to precast concrete panels to be used as bridge decking (figure 11-11). This method reduces the interruption of traffic by allowing the upgrade to be conducted in stages and not having to wait for a recast deck to cure.

*b. Steel grid deck.* A varying amount of strength can be added to a structure by welding the grid to the top flange of the stringers. The strength increase is based on the stiffness that can be generated by the deck to resist bending. If the grid is filled with concrete, it would act as a concrete deck with the welds providing the interface normally achieved by shear connectors.



NOTE: SHEAR STUDS SHOWN ARE ACTUALLY ADDED AFTER PRECAST DECK IS POSITIONED.

*Figure 11-11. Precast deck with holes.*

### 11-10. Posttensioning

Posttensioning can be applied to an existing bridge to meet a variety of objectives. It can relieve tension overstresses with respect to service load and fatigue-allowable stresses, reduce or reverse undesirable displacements, and add ultimate strength to an existing bridge. Posttensioning follows established structural analysis and design principles. A design procedure to posttension steel and composite stringer follows:

*a.* Determine the standards to which the bridge is to be strengthened (loads, allowable stresses, etc.).

*b.* Determine loads and loads fractions for all stringers (dead load, long-term dead load, live load, impact load).

*c.* Compute moments at all critical locations for dead load, long-term dead load, and live and impact loading.

*d.* Compute section properties as required.

*e.* Compute stress to be relieved by posttensioning at all critical locations.

*f.* Design posttensioning (tendon force, tendon eccentricity, distribution of axial forces and moments, and tendon length).

$$f = FF\,(P/A) + MF\,(Pet/I) \qquad \text{(eq 11-1)}$$

where:

$f$ = stress at extreme fiber

$P$ = tendon force

$A$ = area of stringer (composite area if bridge is composite)

$e$ = eccentricity of tendon with respect stringer or bridge

$c$ = distance to extreme fiber

$I$ = stringer moment of inertia (composite section moment of inertia)

$FF$ = force fraction (similar to load fraction for live load)

$MF$ = moment fraction (similar to load fraction for live load)

*g.* Select tendons, accounting for losses and gains:

$$P_{adjusted} = P / (1 - \text{losses }\% + \text{gains }\%) \qquad \text{(eq 11-2)}$$

Assume a 4-percent loss for relaxation of tendon steel, 7-percent loss for potential error in distribution fractions, 2-percent loss for an approximate 10°F temperature differential between tendons and bridge. Assume a 25-percent gain from truck live load.

*h.* Check stresses at all critical locations.

*i.* Design anchorages and brackets. Typical ones are shown in figure 11-12. Experience has shown brackets should be about 2 feet long.

*j.* Check other design factors (beam shear, shear connectors, fatigue, deflection, beam flexural strength, other, as required).

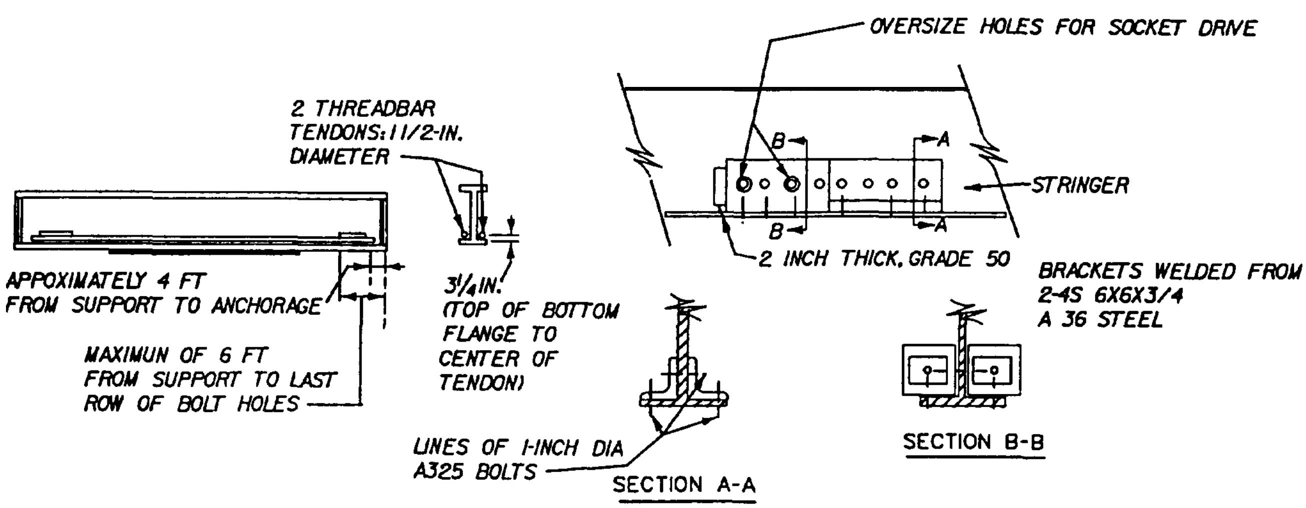
## 11-11. Truss systems

These systems can be strengthened by adding supplementary members to change to a stiffer system or superposition another system onto the existing structure. In cases where the dead load is increased, the substructure must be checked to ensure that it is adequate for the new loading requirements.

*a. Add supplementary members.* This technique is most often applied to Warren and Pratt trusses (figure 11-13). The most common use of supplementary members is to reduce the unbraced length of the top chords in the plane of the truss. Additional lateral bracing may be required to reduce the effective length in the plane perpendicular to the truss. The load capacity of the top chords in compression can be increased by 15 to 20 percent using this technique.

*b. Doubling a truss.*

(1) *Steel arch superposition on a through truss.* A method of upgrading through-truss bridges is to reinforce the existing truss with a steel arch (figure 11-14). A lightweight arch superimposed onto the truss carries part of the dead and live loads normally carried by the truss alone. The truss provides lateral support to the arch. There are two methods of attaching the steel arch to the truss and both methods may require the end panel verticals to be strengthened to ensure adequate lateral support to the arch. In method 1, the existing floorbeams and stringers are assumed adequate to carry the increased live load. In this




A. TENDON DESIGN

B. BRACKET DESIGN

*Figure 11-12. Design of posttensioning.*

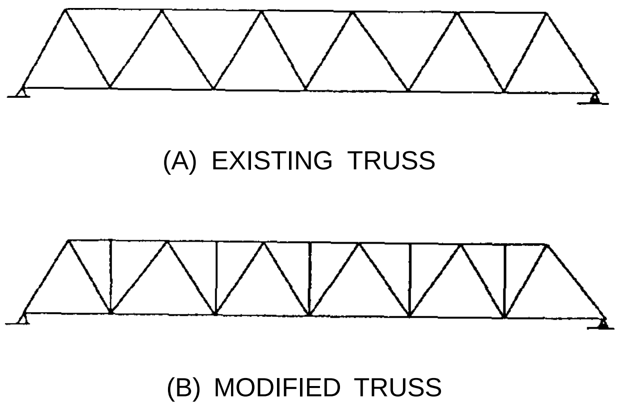



*Figure 11-13. Adding supplementary members to a truss frame.*

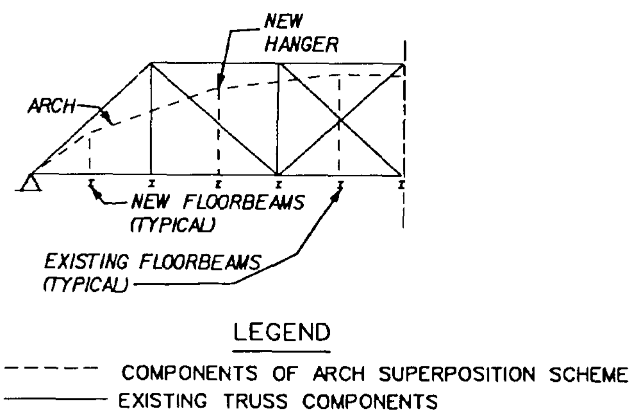



*Figure 11-14. Arch superposition scheme.*

case, the arch support system is attached to the truss at the existing truss verticals. A conservative design includes the dead load of the arch and the truss, along with the full live load. In method 2, the existing floorbeams and stringers will not carry the increased loading. This requires additional floorbeams at the midpoints of existing floorbeams to increase the capacity of the stringers. The existing stringers can be analyzed as two-span continuous beams, with the new floorbeams providing midspan support. Hangers are attached to the new floorbeams, and the arch is connected to the existing verticals. In the determination of the load-carrying capacity of the reinforced system, the analysis of the arch and truss should be conducted separately, with the two-span continuous stringers providing the loads to each. As an alternative to these methods, the arch can be posttensioned along the bottom chords. Posttensioning will reduce horizontal forces transferred by the arch to the abutments.

(2) *Superimposing a bailey bridge.* Superimposing Bailey trusses onto pony or through-truss bridges is a temporary upgrading method. Nor mally the Bailey trusses are a few feet longer than the existing truss and are supported by the abutments. The Bailey trusses are connected by hangers to the existing floorbeams (additional floorbeams may be added and connected to the Bailey truss if the stringers are inadequate). The hanger bolts are tightened until the existing truss shows some movement, indicating complete interaction between the Bailey truss and the existing truss (figure 11-15). The Bailey truss is placed inside the existing truss and blocked and braced against the existing truss to provide lateral bracing to the Bailey truss. This may restrict sidewalk or roadway width. Design data for the Bailey bridge truss are provided in Army TM 5-312. A design procedure for this upgrade is as follows:

*(a)* Determine additional moment capacity required of the Bailey truss.

*(b)* Determine initial Bailey truss assembly that meets required moment capacity (Army TM 5-312).

*(c)* Replace the existing truss with a beam equivalent flexural rigidity.

*(d)* Replace the selected Bailey truss with a beam of equivalent flexural rigidity.

*(e)* Consider adding additional floorbeams between existing beams if the stringers are inadequate, and connect the Bailey truss to the old and new floorbeams.

*(f)* Connect the two trusses rigidly at the points of application of the loads so that they deflect simultaneously an equal amount. The loads carried by each truss can then be determined based on deflected values and flexural rigidity. If the Bailey is inadequate, select another truss configuration with greater moment capacity.

*(g)* Check required shear capacity.

*(h)* Design hangers, lateral bracing, and bearing supports. If separate bearing supports are used as shown in figure 11-15, the Bailey truss adds no additional dead load to the structure.

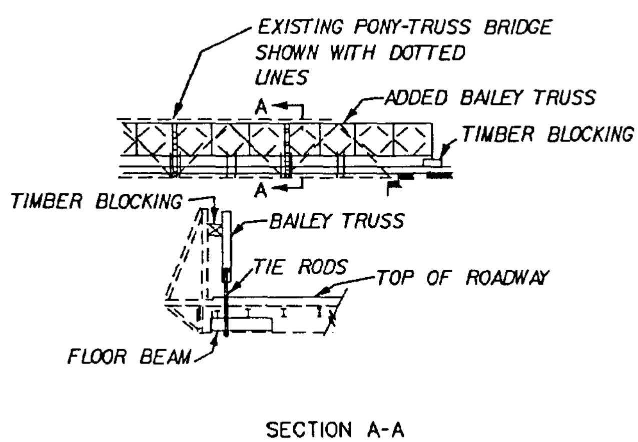



*Figure 11-15. Reinforcing a pony truss with Bailey trusses.*

# CHAPTER 12

# TIMBER BRIDGE MAINTENANCE, REPAIR, AND UPGRADE

## Section I. PREVENTIVE MAINTENANCE

### 12-1. General

When adequately protected, timber is a very durable building material. The preventive maintenance program for timber involves protection from water and insect damage and the repair of damage from these sources and mechanical abrasion.

*a. Water damage.* Timbers placed on the ground or at the waterline and continually exposed to wet and dry cycles are subject to rotting. It is helpful to elevate these members with concrete footings or enclose them in concrete. To prevent water from penetrating the wood, the timber itself must be treated as well as any holes or sawed ends of the timber.

(1) *Preservatives for timber treatments.* The penetration of the preservative normally ranges from 1 to 3 inches into the surface.

*(a) Creosote pressure treatment.* This is the most effective method of protection for bridge timbers.

*(b) Pentachlorophenol (penta-oil treatment).* This is a heavy oil solvent applied using pressure methods.

*(c) Inorganic salt solutions.* The salt solution is applied using pressure and provides less water repelling than other treatments. The salt solution can corrode any hardware used to construct the bridge.

(2) *Holes.* Anchor bolts, drift pins, and lag bolts create holes where decay and deterioration often begins. These holes should be protected from moisture penetration by swabbing with hot asphalt or treating with creosote using a pressure bolt-hole technique.

(3) *Timber ends.* The natural opening in the grain of timber ends allows easier water penetration. If the end is cut, it should be painted with a preservative or swabbed with hot asphalt. The ends of the exposed members should be capped with a thin sheet of aluminum, tin, or similar material (figure 12-1).

(4) *Pile ends.* Two options exist for treatment of pile ends.

*(a)* Drill ¾-inch holes evenly spaced into the pile top 1½ inches deep, fill holes with creosote, and cap with lead sheeting (figure 12-1).

*(b)* Clamp an iron ring around the top of the pile, pour hot creosote into the ring, and allow the pile to absorb the creosote, remove the ring, and cap the pile.

(5) *Debris.* Accumulated debris should be removed from any timber surface. Debris holds moisture which will penetrate into the timber member.

(6) *Bark.* The bark of native logs should be removed if it is not removed during construction. This prevents moisture from being trapped between the wood and bark.

*b. Insect attack.* The insects that attack timber can be classified as either dry land insects (termites, carpenter ants, and powder-post beetles) or marine borers (wood louse or limnoria). The most common treatment for dry land insects is to pressure treat the wood with the proper poison and keep careful watch for reinfestation. Marine borers commonly enter the wood through bruises, breaks, or unplugged bolt holes. The area of infestation generally runs from the mudline to the water level at high tide. The best method of control of marine borers is prevention of infestation. Preventive maintenance for marine borers is conducted for several different stages of infestation.

(1) *Prevent bruises.* Install buttresses to protect the structural members from damage by wave action, current flow, or floating debris.

(2) *Treat damaged wood.* Plug or coat all holes, bruises, and freshly sawed ends with heavy creosote.

(3) *Flexible barrier.* Install a flexible PVC barrier when a pile loses approximately 10 to 15 percent of its cross-sectional area.

*(a) Piles.* Piles should be protected 1 foot below the mudline and 1 foot above high tide (figure 12-2, part a). Sheath the pile with a 30-mil PVC sheet. A half-round wood pole piece is attached to the vertical edge of the PVC sheet to help in the wrapping process. (Note: A pile with creosote bleeding from its surface must first be wrapped with a sheet of polyethylene film prior to installing the PVC wrap to prevent a reaction between the PVC and the creosote.) Staple lengths of polyethylene foam, ½ by 3 inches, about 1 inch from the upper and lower horizontal edges of the sheet. Fit the pole pieces together with one inserted into a pocket attached to the bottom of the other pole. Roll the excess material onto the combined pole pieces and tighten around the pile

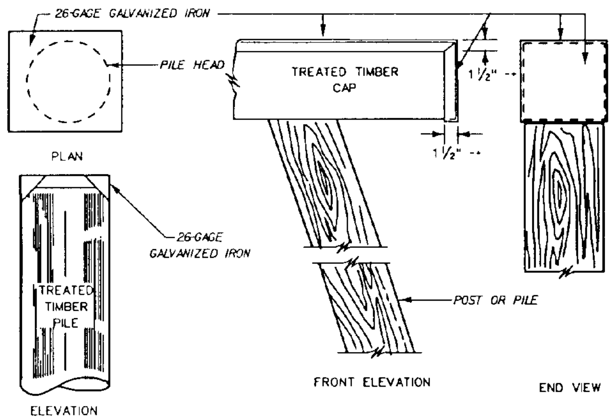



*Figure 12-1. Protective covers for timber members.*

with a special wrench. Secure the wrap and poles with aluminum alloy rails. Nail rigid plastic bands at the top and bottom directly over where the polyethylene foam is located under the wrap. Install additional bands on equal distance centers between the top and bottom bands.

*(b) Braces.* Use wrapping when the braces have light damage or to prevent damage from occurring. Remove the bolt which secures the brace to the pile. Wrap the freed end with 20-mil flexible PVC sheeting. Drive the bolt through the wrapping and existing hole. Rebolt the brace to the pile. Wrap the remainder of the brace in the sheeting. Wrap bolt connections as shown in the first steps.

(4) *Concrete barrier.* When the pile has lost 15 to 50 percent of its cross-sectional area, a concrete barrier can be poured around an existing pile to provide compressive strength and a barrier to marine borers (figure 12-2, part b). To accomplish this, clean the pile to remove foreign materials. Place a tube form (fiberglass, metal, plastic, etc.) around the pile and seal the bottom of the form. Pump concrete grout into the form from the bottom to the top, thus forcing the water out of the form as the grout is placed.

*c. Mechanical abrasion and wear.*

(1) This is an important consideration when timber is used as piles or decking material. Piles are subject to abrasion and wear from the current and tidal flow and the effect of debris carried by these flows. Methods available to help prevent problems in this area are:

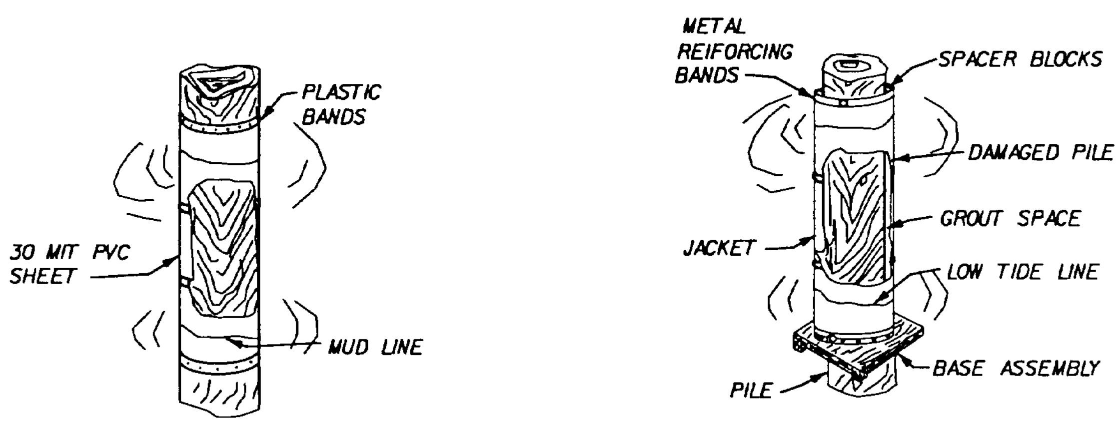
*(a)* Emplace buttresses on the upstream side of the piles.

*(b)* Encase the pile in concrete or steel.

(2) Decks are susceptible to wear and abrasion at locations where sand and gravel are tracked onto the bridge. Two methods to protect the wood deck are:

*(a) Treadways.* Sheet plates or wood planks are placed in the wheel lines to provide a wearing surface.

*(b) Bituminous surface treatment.* A liquid asphalt is applied to the deck and covered with gravel. This protects the deck from wear; it also seals between the planks and contributes to water-tightness. Note that the asphalt wearing surface will not bond to freshly creosoted timber. It is recommended that the deck should be surfaced only after a period of at least 1 year. This permits




A. FLEXIBLE PVC BARRIER　　B. FORM FOR A GROUTED BARRIER

*Figure 12-2. Flexible PVC barrier installed on a timber pile.*

the creosote to leach from the surface before the asphalt is applied.

### 12-2. Fire protection

To prevent tire, covered water barrels with a bucket to distribute water can be placed in convenient locations. The danger of fire can also be reduced by a thin coating of tar or asphalt covered with sand, gravel, or stone chips.

## Section II. REPAIR AND STRENGTHEN TIMBER MEMBERS

### 12-3. General

Repair methods for wood and timber structures are generally directed at correcting one or more of the following problem areas: fungi and/or insect attack, deterioration, abrasion, and overload. The most common repairs for timber structures are retrofitting timber connections, removing the damaged portion of the timber member and splicing in a new timber, and removing the entire member and replacing it with a new member. Common rules for timber repair are:

*a.* There should be at least 1/8-inch clearances between timbers to allow the timber to dry properly.

*b.* When native logs are used for construction, all bark should be removed to reduce moisture penetration into the logs.

*c.* Green or wet timber shrinks considerably when seasoned. Repeated wetting and drying also causes dimension changes as great as 5 to 10 percent in the direction perpendicular to the growth rings. Frequent renailing and tightening of bolts is necessary.

*d.* Care should be taken when using new and salvaged wood together to carry loads because of a difference in the sag and shrinkage of the members. The repair should avoid using new and old stringers in the same panel.

*e.* Wood shims or wedges should be made from heart cypress, redwood, douglas fir, or of the same material as the member.

*f.* Replacement members must have the same dimensions as the existing member accounting for shrinkage.

*g.* Always treat drill holes and cut ends, to prevent water or insect damage.

### 12-4. Connections

The typical timber connection relies on some type of hardware to connect timber members. However, with the improvements made in glues and lamination, glues are becoming a viable option that can be used to enhance the connection. They provide a bond between the wood surfaces and prevent moisture penetration into the connection.

*a. Bolts, drift pins, and screws.* The two most common repairs required for these connections are the replacement of the bolts due to rust or damage and retrofitting the bolt hole in the timber. After removal and inspection of the existing bolt or screw, proceed as follows:

(1) No deterioration (provides a snug fit for the bolt). Inject a wood preservative into the hole and replace the bolt.

(2) Slight deterioration (loose fit for the bolt). Drill out the hole to a size that provides a good wood surface. (Note: The diameter of the hole should not be increased to the extent that the wood cross section will no longer carry the design load.) Inject a wood preservative. Replace the bolt or screw with a larger size to tit the increased hole diameter.

(3) Moderate deterioration (hole provides no bearing on the bolt and boring out the hole would reduce the connections load capacity). Remove the deteriorated wood from around the edge of the hole. Inject a wood preservative, and, if possible, coat with tar or creosote. Attach steel plates with holes corresponding with those in the timber connection across the connection to bridge the damaged area. Place bolts through holes in the plates and tighten.

(4) Heavy deterioration (connection is beyond repair). Cut off the damaged portion of the member and splice on a new portion, or replace the members which form the connection.

*b. Wood scabbing.* Scabbing is used to join members together or splice repaired timber members into existing components. Exterior plywood can be used for light loads. However, in most cases standard sawed timbers are used. The first step in any repair of this nature is to check the scabbing for soundness and replace if required. If the scabbing is in good shape, it can be tightened in various ways:

(1) Remove loose nails or screws and replace with larger size.

(2) Add nails or screws to the existing scabbing.

(3) Drill through the scabbing and member and emplace bolts.

*c. Steel connector plates.* Connection plates are made of light-gauge galvanized steel plates in which teeth or plugs have been punched. If the plate must be replaced, the wood surface may be too damaged for the teeth of the new plate to provide a shear interface. In this case, wood scabbing can be used to replace the steel plate or a new steel plate can be emplaced using nails to provide the interface. A loose plate can also be tightened and strengthened by adding nails or screws to the plate.

*d. Nails, spikes, and screws.* These are the most common hardware items used to form wood connections. When these items become loose the only options are to:

(1) Replace the nail or screw with a larger one.

(2) Drive or screw the connector back in place, and add nails or screws to help carry the load of the loose connector.

*e. Deck connectors.* Timber decking is connected to steel stringers with floor clips (figure 12-3) or nails driven into the under side of the decking and bent around the top flange of the steel member (figure 12-3). Composite action is achieved between a concrete deck and timber stringers by either castelled dapping, consisting of ½ to ¾-inch cuts in the top of the stringer; castelled dapping in conjunction with nails or spikes partially driven into the top of the stringer; lag bolts at a 45-degree inclination to horizontal; or epoxies.

## 12-5. Repair of graded lumber

When lumber is damaged to the point that the structural integrity of the member is in question, scabbing or slicing of the member may be required to bridge the damaged area.

*a. Scabbing.* Scabbing can be used when the member is moderately damaged and the addition of the scabbing allows the member to carry its design load. The method of scabbing used depends upon the type of timber member:

(1) *All members.* Clean and treat damaged area. Relieve the member of any load, if possible. Place scabbing on the sides and/or the top and bottom of the member to transmit the load across the damaged area. The scabbing can be of a like wood, steel plate with bolt holes, or a steel plate connector.

(2) *Beams and stringers.* A steel plate can be scabbed onto these members to repair longitudinal cracks as follows (refer to figure 12-4): drill holes through the deck on either side of the stringer at a minimum distance equal to the beam depth past the damaged area; drill an additional set of deck holes past the other end of the damaged area; place draw-up bolts through the holes that extend past the bottom of the existing beam (use washers or support straps to help prevent pull through); place a steel retaining plate on the bottom of the stringer and hold it in place with support straps and nuts on the draw-up bolts; and tighten the retainer plate in place. This process will strengthen the damaged area by providing a steel cover plate across the damage, closing any slits or cracks in the wood, and by creating a composite action between the stringer and the deck.

(3) *Piles.* A reinforced concrete scab or jacket can be placed around a partially deteriorated pile to restore the strength. The procedure is the same as placing protective cover around a pile with the

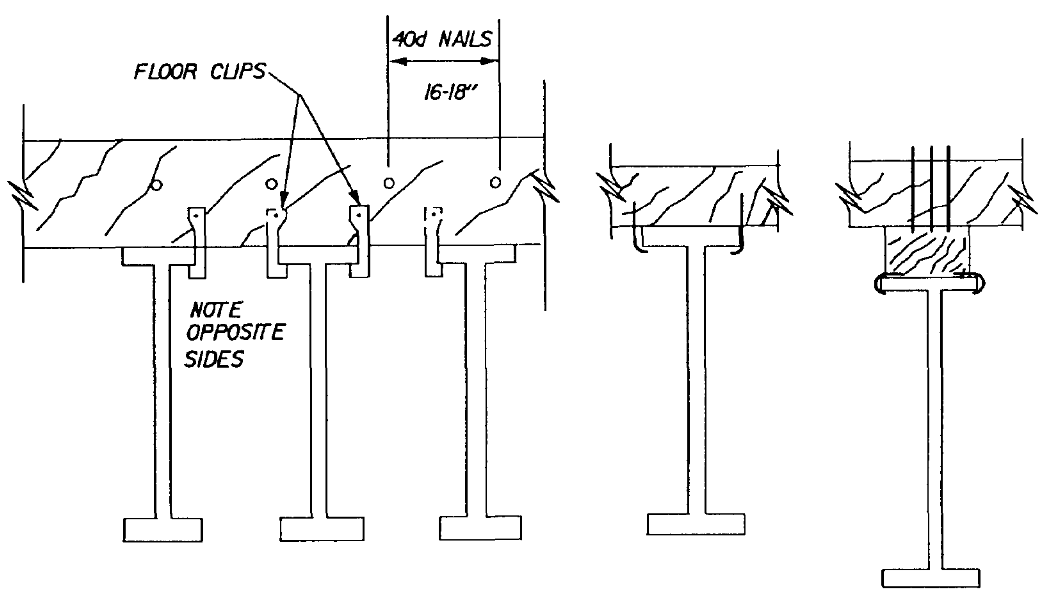



*Figure 12-3. Common deck connectors.*

exception that reinforcing bars are placed inside the form for added strength (see paragraph 12-1).

(4) *Caps.* Caps can be scabbed to extend the bearing area where the bottoms of stringers or laminated decking has deteriorated over the cap. The repair consists of attaching 6-inch-thick timbers with a depth equal to the cap to each side of the existing cap as follows (figure 12-5). Use a template to lay out 4-inch O-ring connectors on the cap and scabs. Cut O-rings and drill ¾-foot holes through the cap and scabs. Insert O-rings in the cap. Position scabs and clamp or bolt into place. Insert bolts through scabs and cap using O.G. washers on both ends of the bolt, and tighten into place.

*b. Splicing.* Splicing is required when the lumber is too severely damaged to carry its design load (figure 12-6). To splice, remove the damaged portion of the wood member. Treat the freshly cut end of the member and the replacement member. Then, nail, screw, or bolt scabbing onto the existing timber and replacement to join them together.

## 12-6. Repair of piles

When piles are damaged or deteriorated to the point that the structural integrity of the pile is in question, it may be more advantageous to repair the existing pile than to drive a replacement. The key to pile repair is that the existing pile must have good bearing as part of the foundation. The

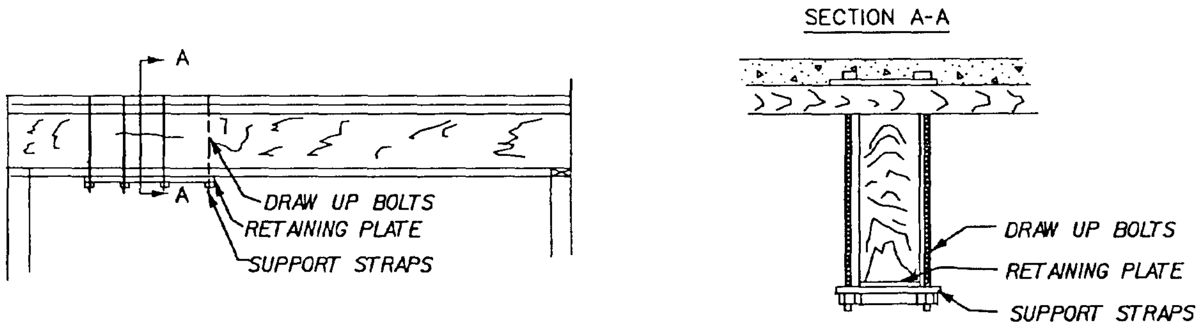



*Figure 12-4. Repair of cracked or split stringers*

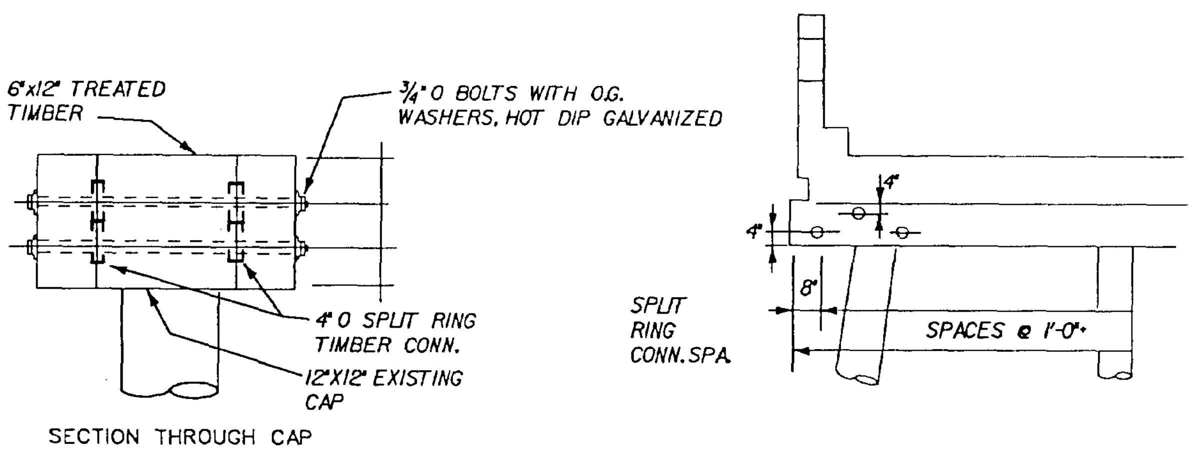



*Figure 12-5. Timber cap scabs provide additional bearing.*

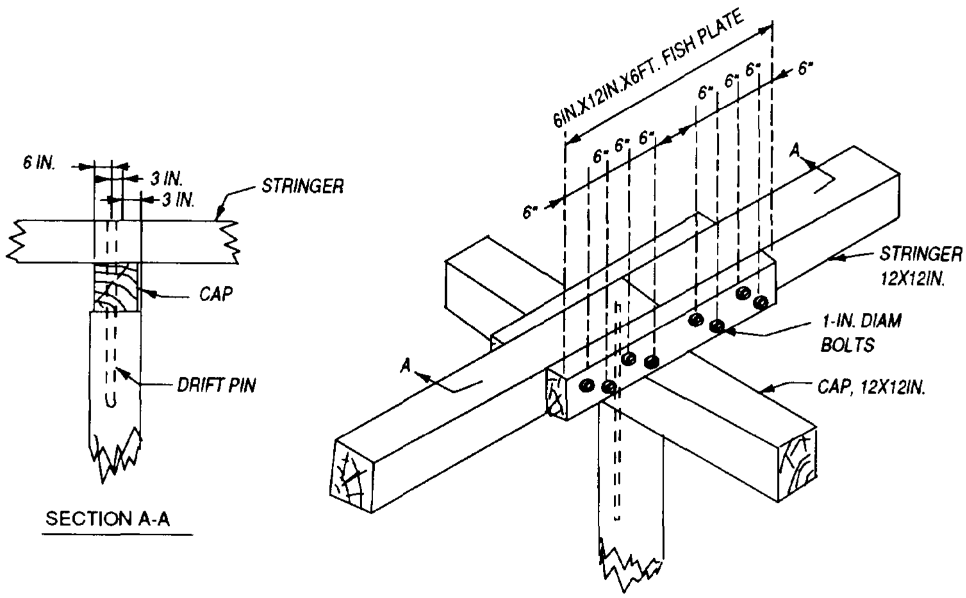



*Figure 12-6. Stringer splice.*

method of repair chosen depends upon the type of pile damage:

*a. Pile damage extending below the waterline.*

(1) *Single-pile steel reinforced splice (figure 12-7, part a).* Sever the pile approximately 2 feet below the mudline. Cut a stub pile the length of the defective portion. Connect the ends of the stub pile and the existing pile with a center drift pin or dowel with a ¾-inch diameter and 18 inches long. Reinforce the joint by placing three angle sections 2 feet long (1.5 inches by 1.5 inches or 2 inches by 2 inches) at each third point around the circumference of the pile connection. The angles will be held in place by a minimum of four lag screws (4 inches long) per angle.

(2) *Multiple pile steel reinforced splice (figure 12-7, part b).* Sever the piles about 2 feet below the mudline. Place a mudsill on the portion of the piles left in place. Secure even bearing on the piles. Tamp earth between piles for an even sill support. Ensure that the cross section of mudsill equals the bent cap and extends 3 feet beyond the piles. Connect pile stubs between the mudsill and cap using the drift pins and angles described for the single pile. If the pile damage extends above the waterline, sever the pile about 2 feet below the damage and proceed as previously described for a below-water single pile. Seal the joint with creosote or asphalt.

*b. Single pile damage above the groundline (figure 12-8).* Remove the soil around the pile to below moisture line. Construct cribbing or place struts for support jacks. Place jacks and jack up cap ½ inch to 1 inch. Cut the dowel connecting the cap to the pile. Cut the deteriorated pile off below the permanent moisture line. Make cut at a right angle to the centerline of the pile. Cut the new pile ¼ inch longer than the removed section. Place the concrete form and reinforcing bars into position. The form must allow a minimum of 6 inches of cover around the pile. The form can be made from steel culvert or steel drums and need not be removed. Place the new pile section on the existing pile stump. Ensure an even contact at the bearing points and check to make sure the rebar has not shifted. Pour Class II concrete into the form and slope the top of the pour to allow water to run off. Reattach the cap to the pile with a dowel or an exterior steel plate.

*c. Settlement and bearing loss of a pile due to deterioration.* Place cribbing or struts adjacent to the pier and jack the stringers off the cap to an elevation ½ inch higher than desired. Cut the tops off the decayed pile. Cut a shim ¼ inch less than the space between the cap and the pile head and treat the pile head and shim. Place the shim into position. Lower jacks and fix the shim into position (figure 12-9). Toenail the shim to the pile. Dowel through the cap and repair. Nail fish plates across the repair and remove the cribbing.

*d. Damage to fender piles.* Piles that have been broken between the top and bottom wales (figure 12-10) can be repaired as follows: cut off the pile below the break; install a new section, secured with epoxy; fit a strongback into position behind

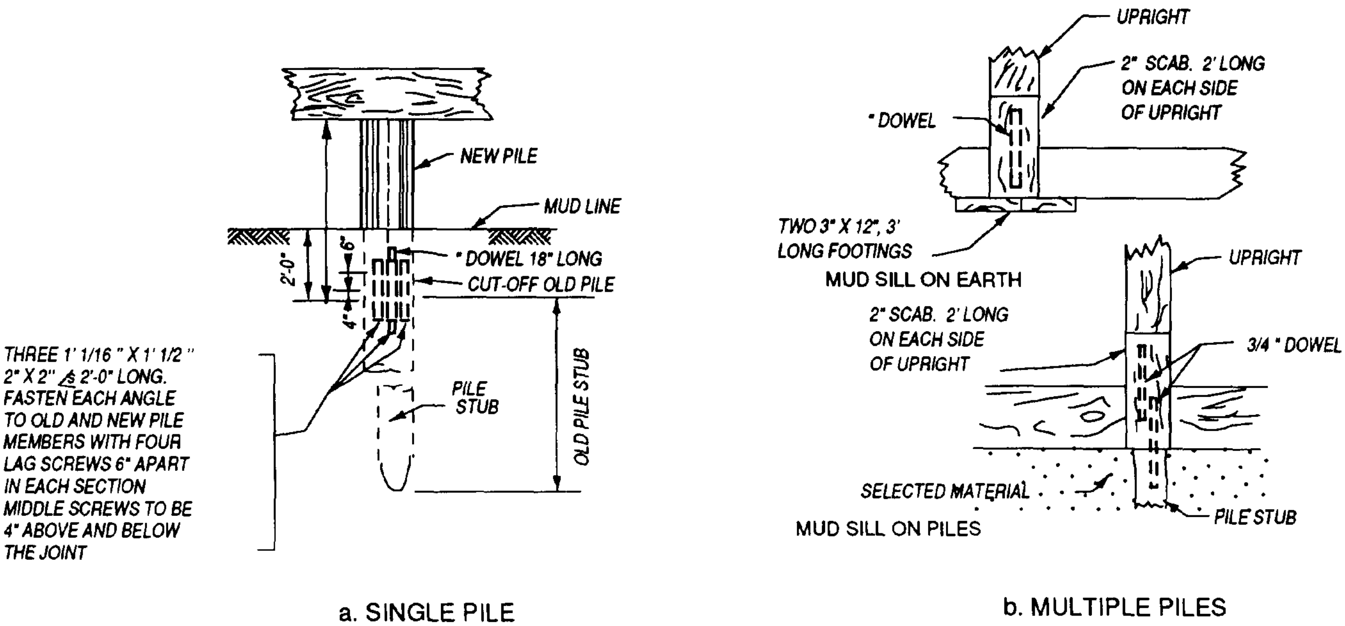



*Figure 12-7. Timber pile repair.*

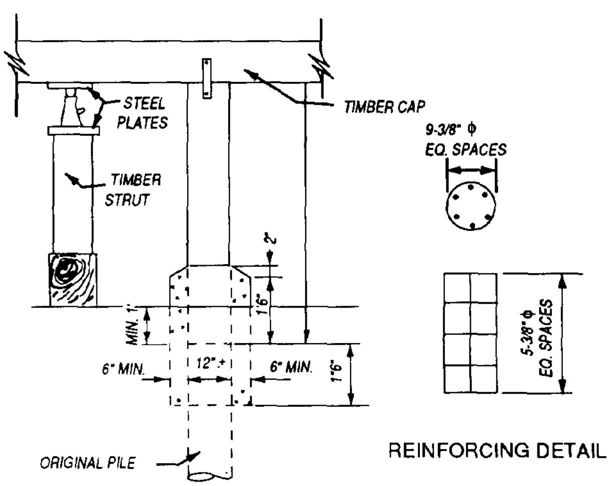



*Figure 12-8. Concrete jacket supporting a timber pile splice.*

the pile with bolts; and connect a metal wearing shoe on the front side of the pile.

## 12-7. Repair of posts

Damaged bent posts can be repaired in much the same way as single piles or through splicing across the damaged section.

## 12-8. Repair of sway bracing

Repairs involving sway bracing may include the erection of bracing to help stabilize a pier or the replacement of existing bracing. When bracing is desired, measurements should be taken and the timber cut and treated prior to the repair operation.

*a. Installation of bracing.* Temporarily attach bracing to piling in its final position using galvanized nails. Locate and drill bolt holes through the bracing and pile. The holes should be the same diameter as the bolts. Treat all holes with a hot oil preservative. Install bolts, washers, and nuts and tighten into place.

*b. Repair sway bracing.* Locate the end of the deteriorated or damaged brace. Cut off the damaged portion to the nearest pile. Take the required measurements for the new bracing and cut the timber to size. Drill bolt holes in the new bracing, rebolt the bracing to the piling using existing holes when possible, and drill new holes in the piles to realign bracing. Treat all timber cuts and holes with hot oil preservatives followed by a coating of hot tar.

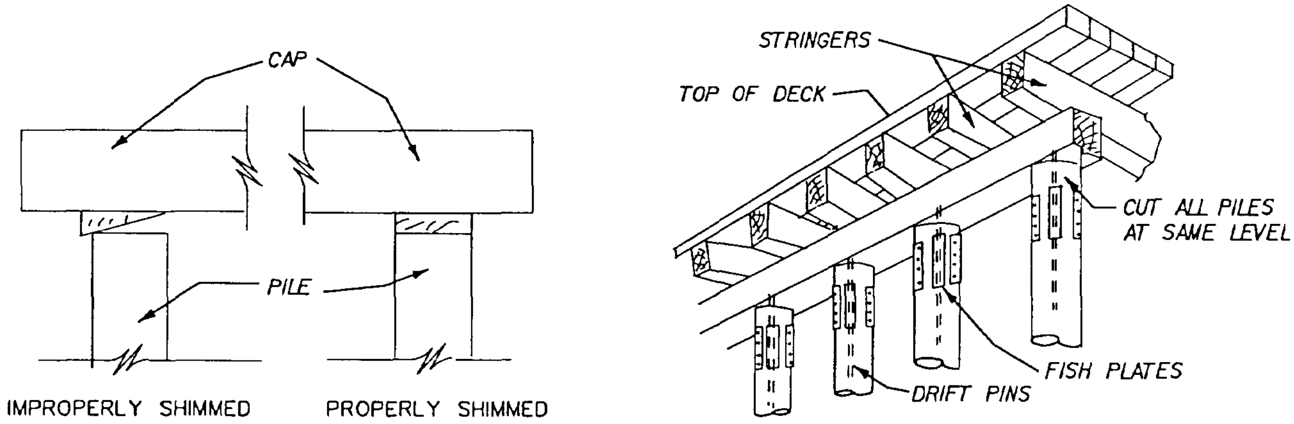



*Figure 12-9. Shimming timber piles.*

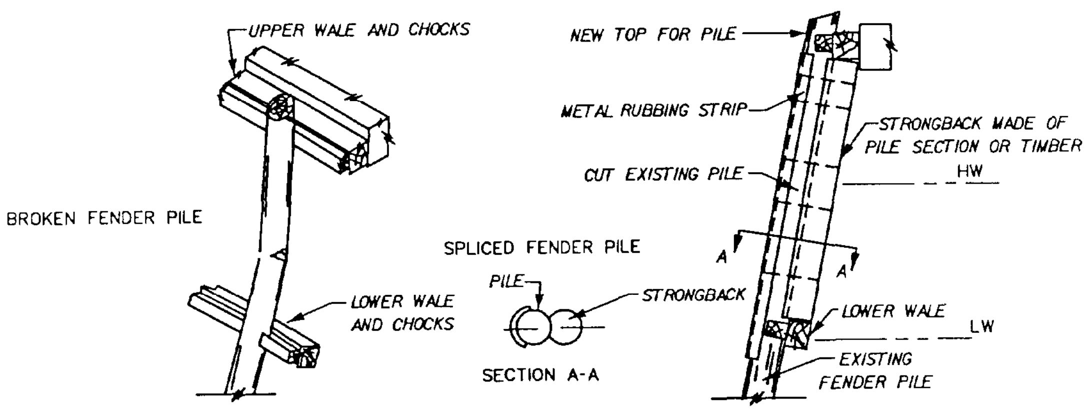



*Figure 12-10. Fender pile repair.*

## Section III. MEMBER REPLACEMENT

### 12-9. Replacement of tension timber components

These members can be replaced using the same procedures outlined in paragraph 11-6 for steel members.

### 12-10. Replacement of compression timber components

*a. Piles.* There are three methods that can be used to replace a damaged pile:

(1) Pull the existing pile and drive a new pile.

(2) Drive a new pile along side the existing pile as follows (figure 12-11, part a): locate the centerline of the stringers nearest to the pile to be replaced, cut a hole through the deck to drive the new pile, remove bracing which interferes with pile driving. Set pile at a slight batter so that it is plumb when pulled into position. Drive to a specified bearing. Install U clamps and blocking around the pile being replaced or on adjacent piles if the existing pile has no load carrying capacity. Place a jack on the block system, and jack the cap off the piles. Cut the new pile ¼ inch below the cap, and place copper sheeting on the pile head. Pull the pile into position. Lower jacks and dowel or strap the cap to the pile. Repair and replace bracing and deck.

(3) Leave the existing pile in place and add new piles as follows (figure 12-12): cut holes in the deck to drive piles, and drive piles on either side of the damaged pile, perpendicular to the bent. The new pile should off set at least one pile width to one side of the damaged pile. Cut the tops of the new piles and place a support across the tops of the new piles to form a cap under the existing pile cap. The two caps should be in contact with each other. Use wedges to ensure that the load is transferred to the new bent.

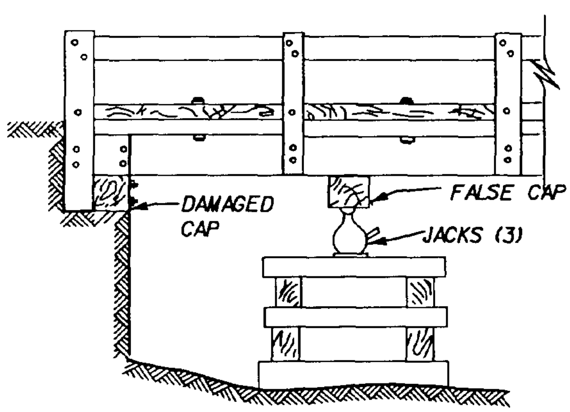
*b. Bent post.* Replace as follows: install a temporary support parallel to the damaged post, remove the existing post, install a new post and wedge into place to ensure proper load transfer, drive a drift pin through the pile cap, wedge into the post to secure into position or nail the wedge into place, cut the wedges off flush with the cap, post and connect the post to the sill, and cap with scabs.

*c. Caps.* To replace caps, temporary or false bents should be constructed to support the deck and floor during the replacement operation (figure 12-11). The new caps should be given a free, even bearing on each pile or post support. The cap should be fastened to each post or pile by drift pins and spikes.

## 12-11. Replacement of flexural timber components (stringers)

Stringers should be lined up to a true plane for new or replacement wood (figure 12-13). Stringers in good condition and of proper size may be salvaged and reused. New and salvaged stringers should not be used together in any one panel because of differences in sag and shrinkage between the new and old stringers. When selecting material for new stringers, it should be of the same width and depth as the other stringers in the panel; however, in case of emergency, the best available size may be used temporarily. The stringers should be wedged as tightly against the deck at the center of the span as they are at the end; do not attempt to fit to the deck sag by adzing. As the new stringers acquire sag, the wedges will be tightened to compensate. The procedure for adding or replacing stringers is as follows:

*a. Under-the-deck method (figure 12-13).* Place two jacks on each cap in adjoining bays next to the stringer being replaced. Use steel plates between the jack faces and the timber. Stop traffic during the jacking operation and jack the deck up ¼ to ½ inch to clear the stringer. Cut a wedge out of one end of the stringer, and bevel the corners on the other end. If the replacement timber is warped, place the camber up to provide bearing on all the deck members. Place the stringer's wedged end on




A. JACKING FROM CRIBBING.  B. JACKING FROM A BENT PILE.

*Figure 12-11. Jacking methods for timber cap replacement.*

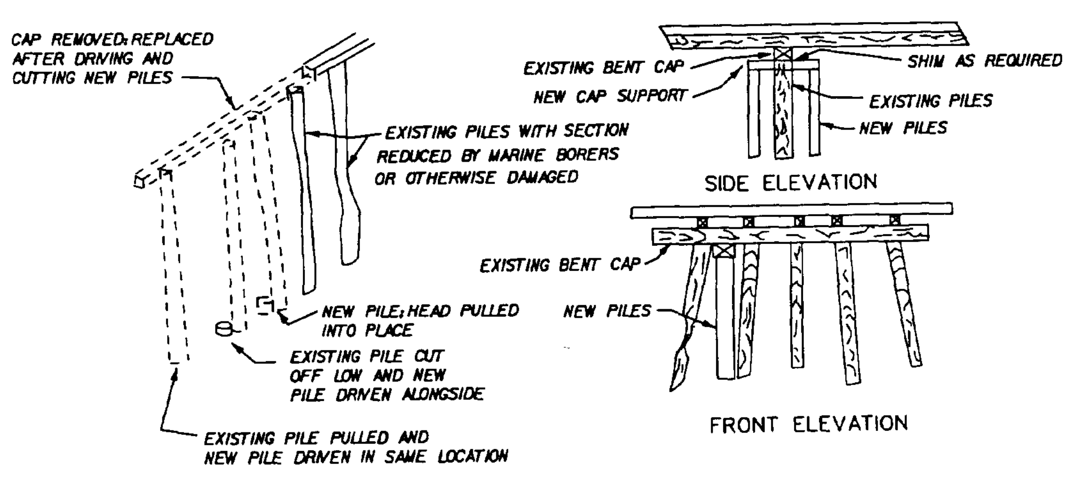



*Figure 12-12. Pile replacement methods.*

its cap, and push it far enough onto the cap to allow the opposite end to be placed on its cap. Lift the beveled end of the stringer onto the cap. Anchor a "come-along" to the cap under the beveled end, and attach the cable to the wedged end of the replacement stringer. With the come-along, pull the new stringer into a final position that provides an equal bearing on each cap and wedge the under side of the stringer to provide contact with the deck. Remove the support equipment, and nail the wedge into position in such a fashion that the nails can be removed and the wedges adjusted to account for sag.

*b. Above-the-deck method.* Cut the deck along each side of the stringer to be replaced. Remove enough decking to allow one end of the stringer to rotate on the cap enough for the other end to clear the far side cap when it is lifted. Lift the far end of the stringer with a cable through a precut hole in the deck clear of the cap. Jack or pull the stringer into final position. Replace the decking.

## 12-12. Replacement of timber decking

*a. Timber flooring.* Floor planks should be laid with the heart side down because it is more resistant to decay. A ¼-inch spacing should be provided between planks for drainage, expansion, and air circulation. Structural grade hardwood planks, 6 to 10 inches wide, are preferred as decking material because wider planks have a tendency to curl. All nails or spikes should be driven so that their heads are imbedded into the plank. Planks of the same thickness should be placed adjacent to each other with a full, even bearing on the stringers. Wedges should not be used to level flooring because they are easily dislodged and leave the flooring in a loose and uneven condition.

*b. Wheel guards.* Replacements should use the same size sections as the original and be fastened with the same bolt spacing. The bolts should be extended through the riser or scupper blocks and floor planks (figure 12-14).

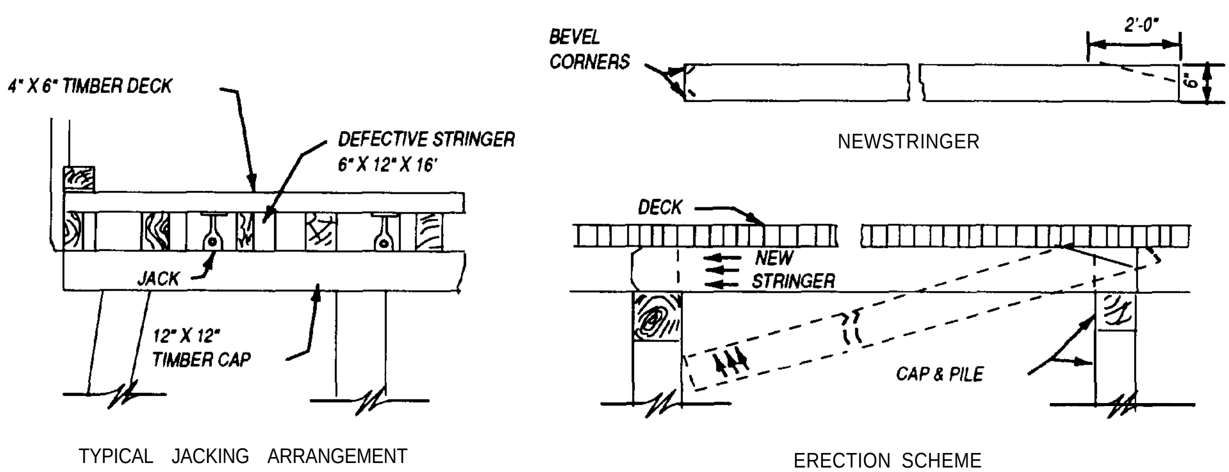



*Figure 12-13. Belowdeck timber stringer replacement.*

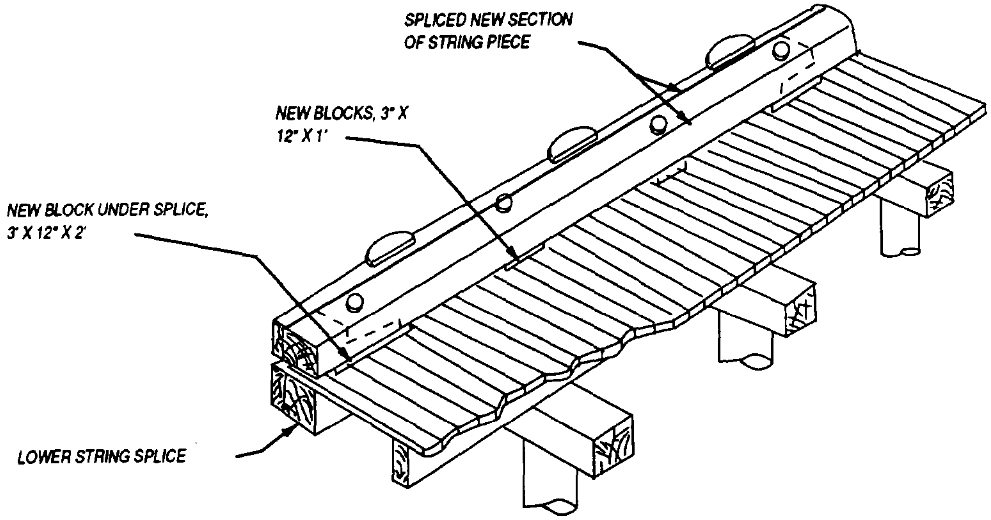



*Figure 12-14. Splicing in a wheel curb.*

## Section IV. TIMBER BRIDGE UPGRADE

### 12-13. Strengthen intermediate supports (piers)

*a. Bent post.* Bent posts can be strengthened by nailing 2-inch thick planks to the cap and sill and the post between them. The planks should be approximately the width of the pier component to which it is nailed. This has the effect of increasing the cross sectional wood area carrying the compressive loads of the bridge.

*b. Concrete encased piles.* Paragraph 12-4 discusses the process of encasing a timber pile in concrete to shore up a timber splice. The same type of technique can be used to extend the reinforced concrete casing the full length of the timber pile. The procedure involves the same steps required in jacketing steel or concrete piles (Refer to paragraphs 11-4 and 13-5).

*c. Helper bents.*

(1) This system can be used to strengthen an entire pier section. It is used when existing piling have lost their bearing and settlement occurs, when the load capacity of the piling is in question, or when the load bearing capacity of an existing pier is increasing. Timber piles are driven through the deck parallel and adjacent to the pile bent and topped with a cap to interface with the stringers. In essence, a new pier is constructed adjacent to the existing pier to help carry the loads (figure 12-15).

(2) Helper bents are installed in the following manner. Locate the centerline of stringers or beams and mark the positions of the helper bent piles parallel to the pier. Cut holes in only one traffic lane at a time. For timber decks, make a cut along the centerline of the stringers and remove enough decking to drive the pile. For reinforced concrete decks, remove sufficient concrete in a square pattern to drive the piles. Cut the reinforcing steel at the center of the hole and bend out of the way. Set the piling and drive to the required bearing. Cut the pile ¼ inch above the existing cap (make allowances for grade differentials due to settlement). Place cover plates over the deck holes and move to the next position. Repeat the same operation until all the piles are driven. Jack up the superstructure ½ inch using the existing pier. Place a timber cap onto the pilings. Lower the superstructure onto the caps of the new piers and strap the caps to the pilings. Shim between the superstructure and the cap as required to obtain the proper bearing. Remove the deck plates and repair the deck. Construct cross-bracing on the new pile bents and between the bents for intermediate bents.

### 12-14. Shorten span length

The strength increase obtained from shortening a timber span is fairly large due to the short spans generally associated with timber bridges. Shortening is accomplished by adding one of the following:

*a. Intermediate piers.* Paragraph 10-22b.

*b. A-Frame.* Paragraph 10-22c.

*c. Knee brace.* Paragraph 10-22d.

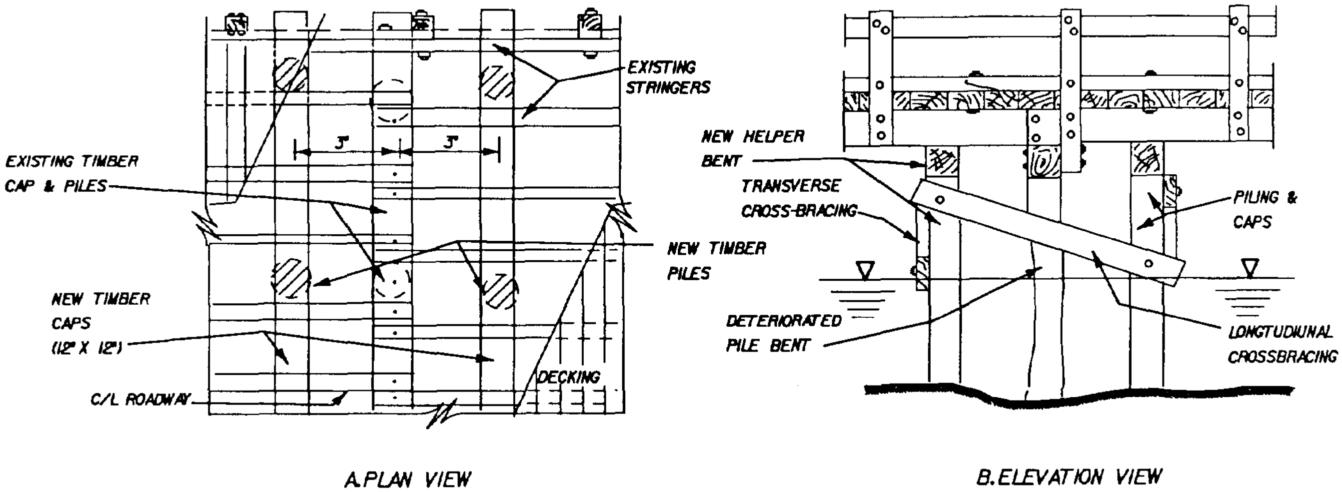



*Figure 12-15. Diagrams of an intermediate helper bent.*

## 12-15. Posttensioning

Many types of posttensioning can be applied to timber structures. The most common and effective methods are the king post, which counteracts bending, and the external stirrup, which reduces shear effects.

*a. King post.*

(1) In effect, the king post shortens the effective length of the reinforced span. One technique that can be used to install the king post to a timber bridge is as follows (figure 12-16):

(2) Install a ¾-inch threaded steel eyebolt through the stringer at an equal distance from each end of the member. Steel plates with a hole for the eyebolt should be used under the eyebolt nuts to help prevent pull through. Note that the eyebolts should be positioned in a low moment area of the stringer and the internal moments generated by posttensioning should be checked. Run a steel cable through the eye of the eyebolt and use u-bolts to tie the cable to the eyebolt. Attach a king post to the underside of the beam at midspan. The king post can be of steel or wood and should have an eye to run a steel cable through. Run a cable through the eye of the king post, and connect the ends of the cable to the cables from the eyebolts using a turnbuckle. Tighten the turnbuckle to provide posttensioning to the stringer.

*b. External stirrups.* External stirrups can be applied to timber stringers to provide shear strengthening in much the same way as stirrups are used to reinforce concrete. Small channels or angles are used as tie plates across the top and bottom of the stringer, and threaded bars tightened into holes in the tie plates form the external reinforcement (paragraph 13-7).

## 12-16. Add stringers

Additional stringers can be installed in an existing bridge to redistribute the bridge loading. The same technique used to replace stringers can be used to install additional stringers under an existing deck (paragraph 12-10).

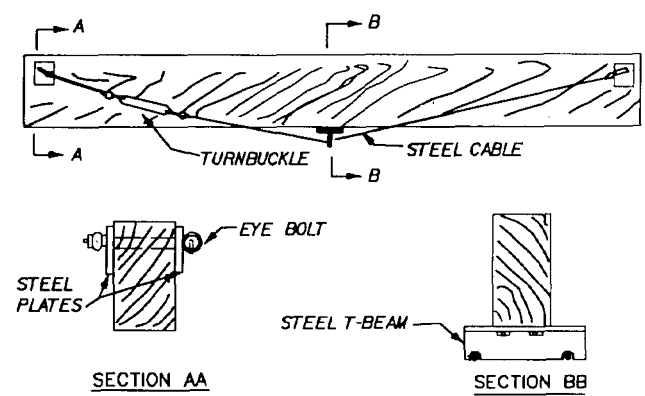



*Figure 12-16. Timber beam strengthened using king post posttensioning.*

### 12-17. Strengthen individual members

Timber members can be strengthened by the addition of steel cover plates to counteract flexure and shear as follows (figure 12-17): Apply a field preservative treatment to the timber and paint the steel cover plates. Attach the flexural cover plate to the timber member using lag screws. Attach shear cover plates to both sides of the member using through bolts. Note that proper spacing of lag screws or bolts will ensure that composite action between the plate and timber stringer occurs.

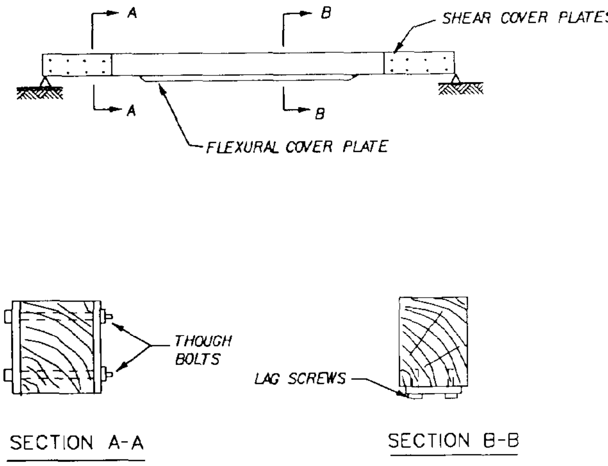



*Figure 12-17. Steel cover plates used to reinforce a timber beam.*

# CHAPTER 13

# CONCRETE BRIDGE MAINTENANCE, REPAIR, AND UPGRADE

## Section I. PREVENTIVE MAINTENANCE

### 13-1. General

Preventing concrete deterioration is much easier and more economical than repairing deteriorated concrete. Preventing concrete deterioration begins in the design of the structure with the selection of the proper materials, mixture proportions, concrete placement, and curing procedures. Even a well designed concrete will generally require follow-up maintenance action. The primary types of maintenance for concrete are surface protection, joint restoration, and cathodic protection of the reinforcing bars. Surface maintenance involves the application of coatings for protective purposes. Joint problems are usually treated with one of a variety of types of joint sealers, and cathodic protection involves the use of anodes connected to the reinforcing bars which will deteriorate in place of the reinforcing bar.

### 13-2. Surface coating

*a. General.* Surface coatings are applied to concrete for protection against chemical attack by alkalies, salt solutions, or other chemicals. The actual need for a coating must first be established, and then the cause and extent of any deterioration, rate of attack, and environmental factors must be considered for selecting the right coating for the job. A variety of coatings and sealants are available for waterproofing and protecting concrete surfaces. Among the products are several types of oil and rubber resins, petroleum products, silicones, and other inorganic and organic materials. Some of these products have been successful in protecting new concrete from contamination by deicing salts and other harmful environmental agents. They have generally been unsuccessful at stopping the progression of already contaminated concrete.

*b. Surface water repellents.* This type of coating helps prevent or minimize scaling from the use of deicers. This is a low-cost treatment that provides a degree of protection for non-entrained concrete or is added insurance for air-entrained concrete placed in the fall and subject to deicing salts during the first winter.

(1) *Linseed oil.* A mixture of 50 percent linseed oil and 50 percent mineral spirits is normally used. The mixture is applied in two applications on a dry, clean concrete surface. The surface coating should be less than 5 mils, and a test strip should be used to help determine the application rate. The normal application rate is 40 square yards per gallon for the first application and 65 square yards per gallon for the second application. This treatment should last for 1 to 3 years.

(2) *Silicone.* Silicone has been used on concrete to minimize water penetration. Care must be taken where moisture has access to the backside of the wall and carries dissolved salts to the front face where it is trapped by the silicone. Silicone oxidizes rapidly and is somewhat water soluble. Treatments are required every 1 to 5 years.

*c. Plastic and elastomeric coatings.* These coatings form a strong, continuous film over the concrete surface. To be effective in protecting concrete, the coating must have certain basic properties: the adhesive bond strength of the coating to the concrete must be at least equal to the tensile strength of the surface concrete; the abrasion resistance must prevent the coating from being removed; chemical reactions must not cause swelling, dissolving, cracking, or embrittlement of the material; the coating should prevent the penetration of chemicals that will destroy the adhesion between the coating and concrete; for proper adhesion, the concrete must be free of loose dirt particles, oil, chemicals that prevent adhesion, surface water, and water vapor diffusing out of the concrete.

(1) *Epoxies.* Epoxies are used, with a solid content from 17 to 100 percent as a clear sealant, with coal or tar mixed as a mortar. As with most thin coatings and sealants, a protective overlay or cover is required if they are exposed to traffic wear or abrasive forces.

(2) *Asphalt.* Asphalt is used as a protective overlay for bridge decks. This surface provides water protection and a protective wearing surface.

### 13-3. Joint maintenance

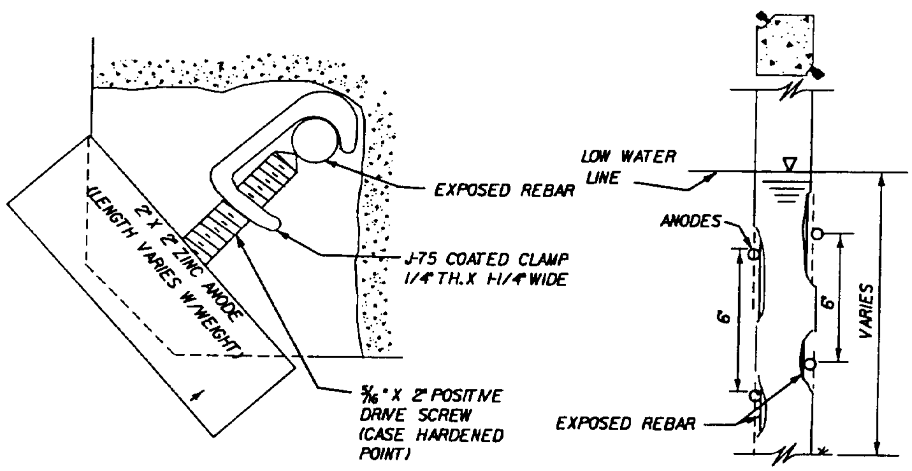
Little maintenance is required for buried sealants because they are not exposed to weathering. Most field-molded sealants require some type of periodic maintenance if an effective seal is to be maintained. Minor touchups in field-molded sealants can usually be made with the same sealant. Where the failure is extensive, it is necessary to remove and replace the sealant. The sealant can be removed using handtools or on large projects by routing or plowing using suitable tools. Sawing can be used to enlarge the joint to improve the shape factor for the new sealant. After the joint has been cleaned it can be resealed. For more information on joints see paragraph 12-12.

### 13-4. Cathodic protection

The only remedial procedure other than replacement that has proved effective in stopping the corrosion process in contaminated concrete is cathodic protection. Compared with the cost of replacement, it is normally much less expensive. There are two types of cathodic protection systems that can be used to prevent corrosion in reinforcing bar. The systems are the impressed current system and the galvanic system.

*a. Impressed current system.* This system uses low-voltage, high-amperage direct current from an external power source to make the reinforcing bar into a cathode. This system is most effective when installed during the construction of decks, piers, stringers, and abutments. During the installation ensure that the reinforcing bars are in good contact with one another; this will allow the current to flow through the reinforcing system. This system can be used to protect the exposed reinforcing bar; however, it is usually not an economical option in this special case. A common power source used in the system is a rectifier which provides DC power from an AC source.

*b. Galvanic system.* This system requires no external power source but uses anodes of a special alloy to generate the current required to suppress the corrosion process. Three common alloys are zinc, magnesium, and aluminum. A procedure used to protect exposed reinforcing bars in concrete piles follows (figure 13-l): Clean an area on the exposed reinforcing bar on which to attach a zinc anode (figure 13-1, part a). Attach one 7-pound anode to every 6 feet of reinforcing bar exposed to brackish or salt water (figure 13-1, part b). Note that additional site testing may be required to adjust the weight of the anode to ensure a 2-year life for the anodes. Less brackish water or fast moving water will affect this life expectancy.




a. ZINC ANODE REBAR ATTACHMENT

b. ANODE ATTACHMENT SPACING

*Figure 13-1. Cathodic protection for reinforced concrete piles.*

## Section II. REPAIR AND STRENGTHEN

### 13-5. General

The repair and strengthen methods discussed in the following paragraphs apply only to conventionally reinforced concrete and specifically do not apply to prestressed concrete. Refer to paragraph 13-17 for a discussion of prestressed concrete members. In concrete repair it is imperative that the causes and not the symptoms of the problem are dealt with. The types of concrete damage, the causes, and the means of determining the causes are discussed in chapters 5 and 8. The repair of deteriorated concrete can be categorized into repairs suited for cracking and those suited for spalling and disintegration. Repair of deteriorated concrete is required when: (1) The deterioration affects the structural design performance of the bridge; (2) The deterioration exposes the reinforcing steel to corrosive action; (3) The lack of a repair will make the bridge unsafe for traffic under normal operating conditions. (Examples: potholes, extensive spalling of the deck, damaged parapets, etc.)

## 13-6. Crack repairs

The large variety of crack types prevents a single repair method. Active cracking may require strengthening of the concrete across the crack to prevent further crack expansion and the application of a flexible sealant that will expand with the crack. Dormant cracks basically require bonding across the crack for the load carrying portion of the concrete and sealing in all other areas.

*a. Conventional reinforcement.* This method is primarily used to bridge isolated cracks in the load-bearing portion of the structure for active and dormant cracks. This repair bonds the cracked surfaces together into one monolithic form (figure 13-2). Proceed as follows: clean and seal the existing crack with an elastic sealant applied to a thickness of 1/16 to 3/32 inch and extending at least ¾ inch on either side of the crack, drill ¾-inch holes at 90 degrees to the crack plane, fill the hole and crack plane with epoxy pumped under low pressure (50 to 80 psi), and place a reinforcing bar (No. 4 or No. 5) into the drilled hole with at least an 18-inch development length on each side of the crack.

*b. Prestressing steel.* This technique uses prestressing strands or rods to compress the crack to close it. (Refer to paragraph 13-12c).

*c. Drilling and plugging.* This repair consists of drilling down the length of the crack and grouting the hole to form a key that resists transverse movement of the section. This technique is most effective on isolated cracks that run in a straight line and are accessible at one end (figure 13-3). To accomplish, proceed as follows: drill a hole (2- to 3-inch diameter) centered on and following the crack its full depth, and clean out the drill hole. The specifics of the remaining procedure are given for:

(1) *Dormant cracks.* Fill the drill hole and crack with a cement grout. If watertightness is required over the bond transfer, fill the hole with asphalt or a like material. When both watertightness and a keying action is required, drill two holes along the crack and fill one with grout and the other with asphalt.

(2) *Active cracks.* Fill the hole with precast concrete or mortar plugs set in bitumen. The bitumen is used to break the bond between the plug and the hole to prevent cracking of the plug by subsequent movement of the crack.

*d. Dry packing.* This process consists of ramming or tamping a low water content mortar into a confined space. This technique is effective in patching holes with a high depth-to-area ratio or dormant cracks. To accomplish, proceed as follows: Undercut the area to be repaired so that the base width is slightly greater than the surface width. For dormant cracks, a slot should be cut along the surface of the crack 1 inch wide and 1 inch deep with a slight undercut. A sawtooth bit is a good tool to use for this purpose. Clean and dry the slot. Apply a cement slurry bond coat of equal parts of cement and fine sand to the faces of the slot. Place dry pack mortar in the slot in 3/8-inch layers and compact each layer with a hard wood stick working from the middle out or a T-shaped rammer for larger areas. If the mortar becomes spongy during the compaction process, allow the surface of the dry pack to stiffen and then continue the compaction. Fill the slot completely and strike flush with

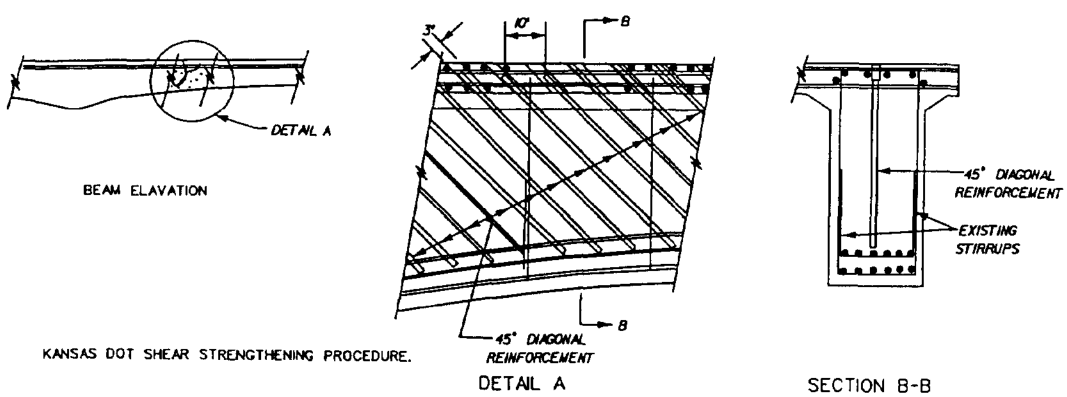



*Figure 13-2. Reinforcing bars inserted 90 degrees to the crack plane.*

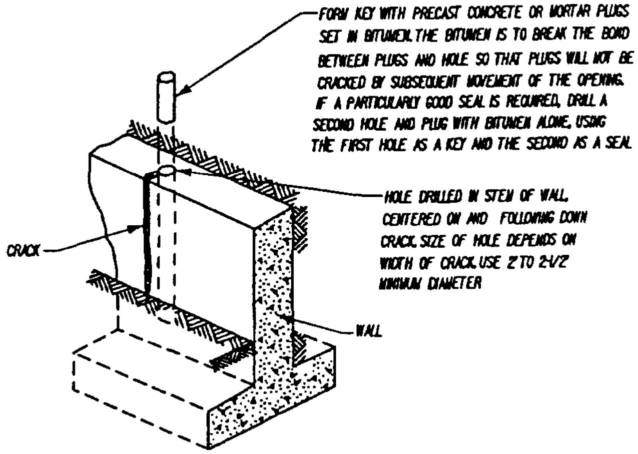



*Figure 13-3. Crack repair by drilling and plugging.*

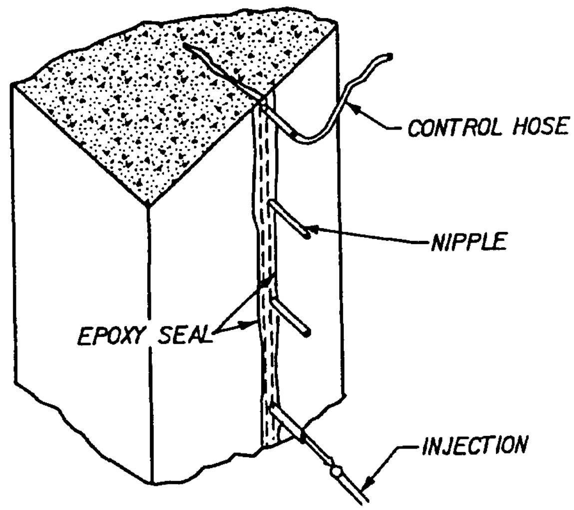



*Figure 13-4. Epoxy injection used to seal cracks.*

the concrete surface using a board or the hardwood compaction stick.

*e. Epoxy injection.*

(1) Cracks as narrow as 0.002 inch can be bonded by injection of epoxy along the crack (figure 13-4). This technique also has been used to repair delamination in bridge decks.

(2) To accomplish, proceed with the following steps. Clean the crack of all oil, grease, dirt, or substances that may retard the bonding process. Seal the surface of the crack by brushing an epoxy along the surface of the crack and allowing it to harden. If high-pressure injection is required, cut a V-shaped groove along the crack ½ inch deep and ¾ inch wide, and fill the groove with epoxy. Install epoxy injection ports. There are three procedures in current use for the installation of injection ports:

*(a) Drilled holes with fittings.* This method is used in conjunction with V-grooves and involves drilling ¾-inch-diameter holes to a depth of ½ inch below the apex of the groove. An injection fitting (small-diameter pipe, plastic tubing, valve stem, etc.) is bonded into the hole.

*(b) Bonded flush fittings.* When cracks are not V-grooved, injection ports are bonded flush with the concrete face. This type of port would be seated directly into the crack, and the face of the port would be flush with the concrete face.

*(c) Interruption in seal.* A portion of the seal is omitted from the crack. For this method, the epoxy injector must have a gasket system that covers the unsealed portion of the crack and allows the epoxy to be injected into the gap without leaking.

(3) After installation of the injection ports, mix the epoxy to conform to the current American Society of Testing and Materials specification for Type I, low-viscosity grade epoxy. Inject the epoxy into the crack using hydraulic pumps, paint pressure pots, or air-actuated caulking guns. Vertical cracks should be injected starting with the port at the lowest elevation and working up. Horizontal cracks can proceed from either end of the crack and run to the far end of the crack. Remove the epoxy seal by grinding or some other means and paint over the injection ports with an epoxy patching compound.

*f. Flexible sealing.* This repair method involves routing and cleaning the crack and fitting it with a field-molded flexible sealant. It is used for active cracks in which the crack is the indication of a joint requirement in the concrete, and the formation of a joint does not impair the capacity of the structure. To install, proceed as follows (figure 13-5): Rout out the active crack to the dimensions that comply with the width and shape factor requirements of a joint having the same movement. Clean the crack and routed area by sandblasting and/or water jetting. Apply a bond breaker at the bottom of the slot to allow the sealant to change shape without forming a stress concentration on the bottom of the sealant. Common bond breakers are polyethylene strips and pressure sensitive tape. Fill the slot with a suitable field-molded flexible sealant in accordance with the proper American Concrete Institute (ACI) specification. Narrow cracks can be sealed without routing by applying a bond breaker over the crack and overlapping the sealant across the bond breaker to seal the crack (figure 13-5).

*g. Routing and sealing.* This method is used to seal dormant cracks that do not affect the structural integrity of the bridge member. The seal prevents water from reaching the reinforcing steel. Proceed as follows (figure 13-6): Rout along the

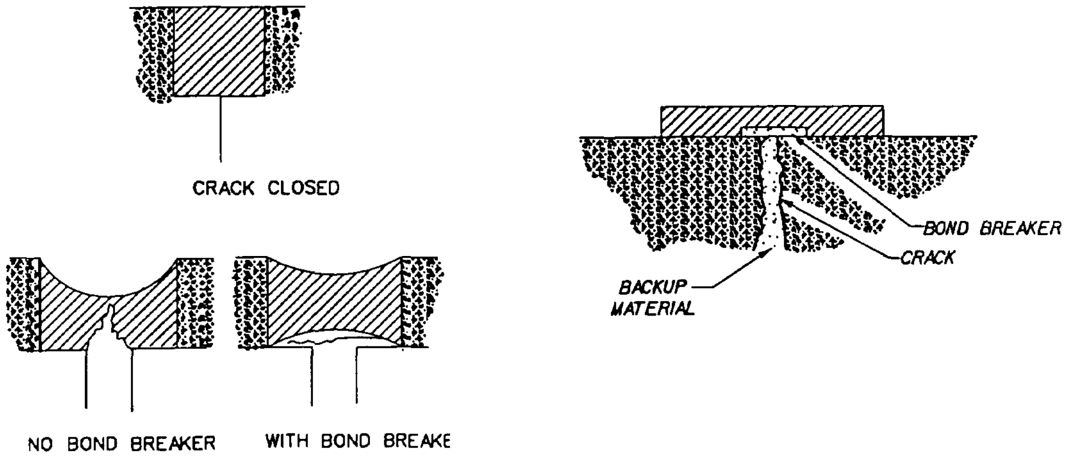



*Figure 13-5. Flexible seals used in concrete crack repair*

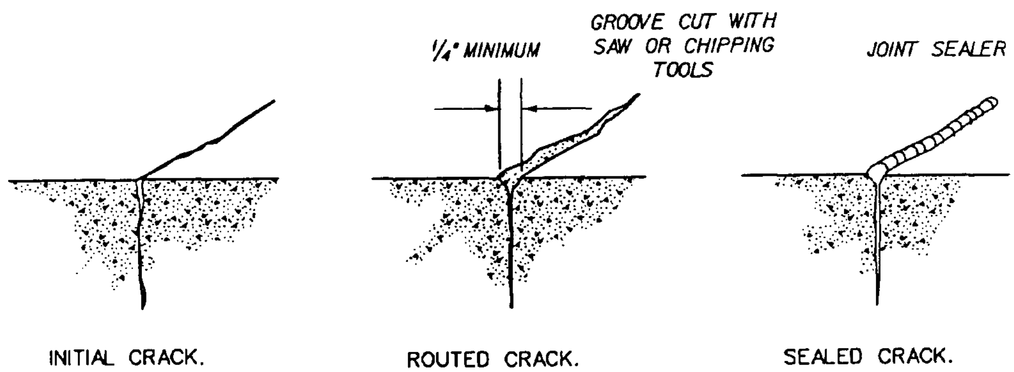



*Figure 13-6. Conventional procedure for sealing dormant cracks.*

crack to provide a minimum surface width of ¼ inch. Clean the cut and allow the surface of the cut to dry. Apply sealant (ACI 504R).

*h. Grouting (hydraulic-cement).* Dormant cracks can be repaired with portland cement containing slag or pozzolans for strength gain. The grout can be sanded or unsanded. Proceed as follows: Clean the concrete along the crack. Install built-up seats (grout nipples) at intervals astride the crack to provide contact with the pressure injection apparatus. Seal the crack between the grout nipples with a cement paint or grout. Pump grout into the crack through the nipples. Maintain the pressure for several minutes to ensure good penetration of the grout. The grout should have a water-cement ratio of one part cement to one to five parts water. The water-cement ratio can be varied to improve the penetration into the crack. Chemical grouts can also be used. They consist of solutions of two or more chemicals that react to form a gel or solid precipitate as opposed to cement grouts that consist of suspensions of solid particles in a fluid. Guidance regarding the use of chemical grouts can be found in EM 1110-2-3504.

*i. Stitching.*

(1) Stitching is the process of drilling holes on both sides of the crack and grouting in stitching dogs (U-shaped steel bars with short legs) that bridge the crack (figure 13-7). Stitching is used to reestablish tensile strength across the crack. Adjacent sections to the cracked section may require strengthening to prevent a crack from forming in the adjacent sections of the concrete.

(2) Install stitching as follows: Drill a hole at each end of the crack to blunt it and relieve the stress concentrations. Clean and seal the crack, use a flexible seal for active cracks. Drill holes on both sides of the crack. The holes should not be in a single plane and the spacing should be reduced near the ends of the crack. Clean the holes and anchor the legs of the dogs in the holes with a nonshrink grout or an epoxy. The stitching dogs should vary in length and orientation to prevent transmitting the tensile forces to a single plane.

(3) The following considerations should be made when using stitching: Stitch both sides of the concrete section where possible to prevent bending or prying of the stitching dogs. Bending members may only require stitching on the tension side of the member. Members in axial tension

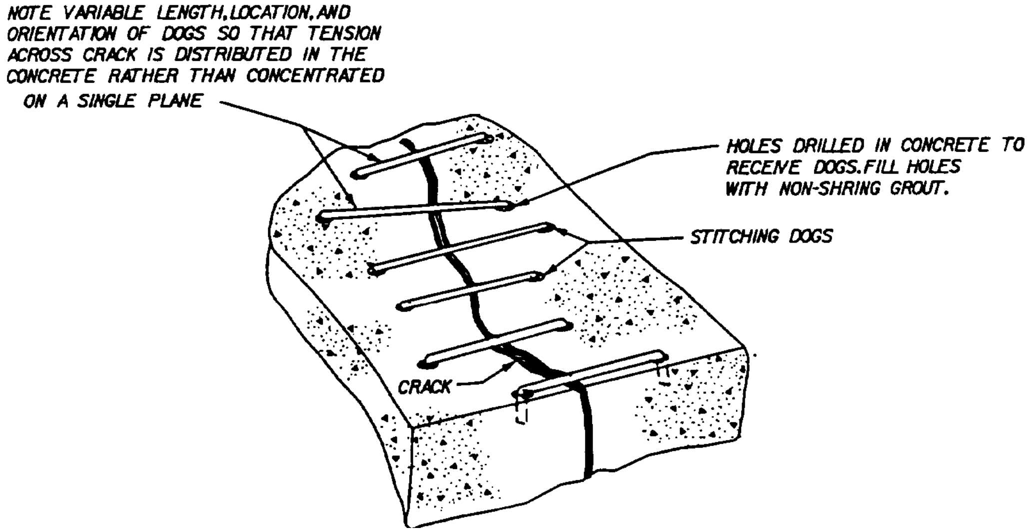



*Figure 13-7. Reinforcement of a crack using stitching.*

must have the stitching placed symmetrically. Stitching does not close the crack, but can prevent its propagation. Stitching that may be placed in compression must be stiffened and/or strengthened to carry this force, such as encasement of the stitching dogs in a concrete overlay.

## 13-7. Spall repair

Spa11 is repaired primarily by removing the deteriorated concrete and replacing it with new concrete of similar characteristics. The process involves the following:

*a.* Analyze the structure to determine the effect of removing the deteriorated concrete down to sound concrete will have on the structure. Determine the need for and the design of any shoring and bracing required to support the structure during the repair.

*b.* The concrete must be removed down to sound concrete or to a depth where the patch is at least ¾ inch thick. Sharp edges, at least 1 inch deep, should be formed around the area to be patched to avoid feather-edging the concrete patch. It is also advantageous to make the bottom of the removed concrete areas slightly wider than the surface to form a keying effect with the new concrete patch. If a large surface area is to be overlaid with new concrete, a minimum of ¼ inch should be removed from the surface. The edges of the overlay should be chipped or cut at about 45 degrees to prevent entrapping air under the overlay. Tools that can be used to remove concrete are: jackhammers, diamond saws, rotary head cutters, high-pressure water jets, thermal lances, and hydraulic splitters. Clean sound surfaces are required for any repair operation, and the absolute minimum amount of concrete to be removed is all unsound concrete, including all delaminated areas.

*c.* The patch area must be cleaned to remove all debris from the concrete removal process. The existing concrete surface and reinforcing steel should then be blast cleaned. The repair is cleaned again and inspected. Any aggregate particles that have been cracked or fractured by scarifying or chipping should be removed to sound concrete.

*d.* Patches should be reinforced with wire mesh attached either to reinforcing bars or dowels to secure the patch to the old concrete. Loose reinforcing bars should be tied at each intersection point to prevent relative movement of the bars and repaired concrete due to the action of traffic in adjacent lanes during the curing period. If new reinforcement is required, an adequate length to attain a lap splice (30 times the bar diameter) must extend from the existing section. If a proper splice is not possible, holes must be drilled into the existing concrete and dowels or anchors installed.

*e.* An interface must be established between the existing and new concrete. Options for this include:

(1) *Epoxy bonding.* Ensure the surface is clean, dry, and free of oil. Apply the epoxy agent to the prepared surface.

(2) *Grout or slurry.* Clean the prepared surface and saturate with water. Remove all freestanding water with a blast of compressed air, and apply a thin coat of grout.

*f.* After surface preparation, the new concrete must be promptly applied to the repair and finished.

*g.* The new concrete should be moist cured for a minimum of 7 days to prevent drying shrinkage and to allow proper strength development. This is most easily accomplished by covering the patch with plastic or wet burlap.

*h.* Shotcrete can also be used to replace concrete in spalled areas. Shotcrete is a mixture of portland cement, sand, and water shot in place by compressed air. It is best used for thin repair sections (less than 6 inches deep) or large irregular surfaces. Shotcrete requires a proper surface treatment similar to that required for a concrete overlay and no form work is needed to confine the mix. This makes shotcrete useful in the repair of vertical walls, beams, and the underside of decks. This technique requires specialized training and guidance on the use of shotcrete as a repair material is given in EM 1110-2-2005.

## 13-8. Joint repair

The maintenance and minor repair of joints is covered in chapter 10 of this manual. Deterioration around a joint in concrete may require a repair of the concrete around the joint in conjunction with resetting the joint. Some of the specialized joint repairs are as follows:

*a. Joint sealant repair.* This repair can be used when the sealant has failed, but the premolded joint filler is still in good condition. The repair procedure is as follows: remove the existing sealant (with tools such as a mechanical joint cleaner or joint plow); score the joint walls with a pavement saw; clean the joint with a mechanical brush and remove debris; place sealant in accordance with the manufacturer's installation procedure.

*b. Expansion joint seal.* This seal can be used to seal open joints, replace failed preformed joint material, and reseal joints sealed with elastomeric seals. The installation procedure is as follows. Determine the required elastomeric seal size in accordance with the guidelines in table 13-l:

*Table 13-1. Elastomeric seal size guidelines*

| *Existing Joint Width (in.)* | *Width of Saw Cut (in.)* | *Size of Joint Seal (in.)* |
|---|---|---|
| ½ | 1 | 1⅝ |
| 1 | 1½ | 2¼ |
| 2 | 2½ | 3½ |
| 2½ | 3 | 4 |
| 3 | 3½ | 5 |

Clean the joint. A high pressure water jet is useful in removing any debris or existing joint material in the joint. Saw cut the joint across the bridge to provide a uniform dimension in the repair joint (figure 13-8, part a). Blow out the joint with compressed air to remove any standing water, dirt, gravel, etc. Brush an adhesive/lubricant onto the inner joint faces. Position the seal over the joint (figure 13-8, part b). Compress the bottom portion of the seal and press into the joint. Ensure the seal is seated to its proper depth and alignment. To make an upward turn with the seal, proceed as

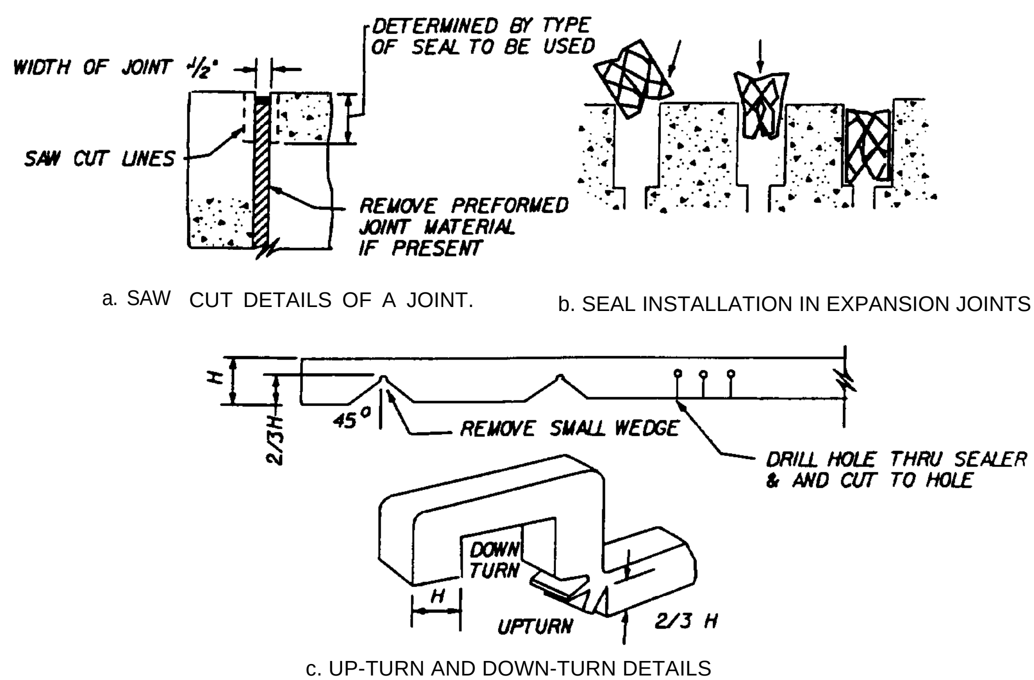



*Figure 13-8. Expansion joint repair with elastomeric seals.*

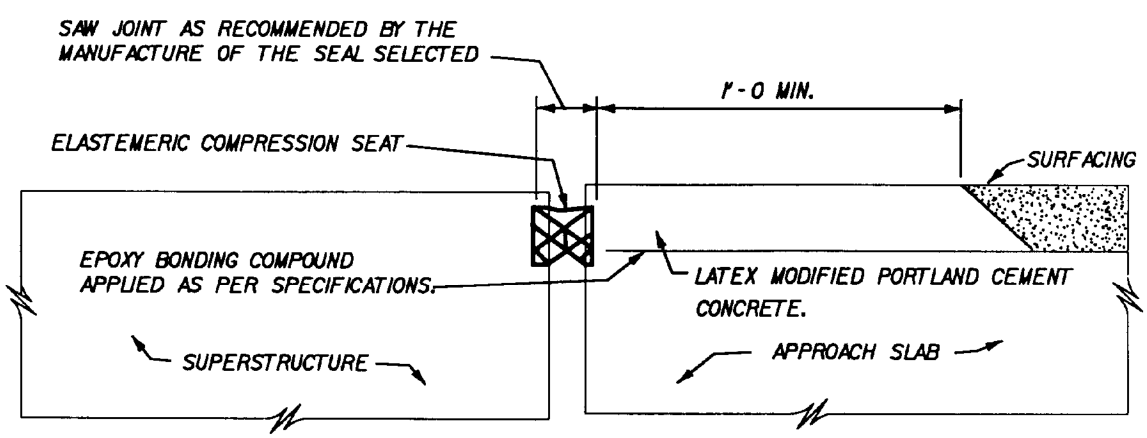
follows (figure 13-8, part c). Drill three ½-inch-diameter holes on line in the elastomeric seal. The holes should be spaced at intervals of 1/3H (H = height of the seal) on lines 2/3H from the bottom of the seal. Cut the lower section of the seal from the bottom, and seal the hole in all three locations. Bend the seal in the desired position and install following normal sealing procedures. To make a downward turn with the seal, proceed as follows (figure 13-8, part c). Drill a M-inch hole along the seal at the location of the bend in the seal in a position 2/3H from the bottom of the seal. Cut a wedge from the underside of the seal by making two intersecting angled cuts (45 degrees) from the bottom of the seal to the ½-inch hole. Bend the seal down and install using normal sealing procedures.

*c. Expansion joint seals with an asphalt overlay.* The installation procedure is as follows (figure 13-9). Saw cut along lines parallel to and 1 foot on either side of the joint at a 60-degree angle away from the joint. Remove the asphalt inside the cut area and clean the concrete deck. Place a filler in the joint to maintain an area between the joint and asphalt. Apply an epoxy bonding compound to the cleaned concrete surface. Place latex modified concrete in the cut area and finish off flush with the existing asphalt. After the concrete has set, saw cut a joint to the required width and depth. Remove all debris and filler from the joint. Apply adhesive to the joint faces and install the seal.

*d. Expansion dam repair.*

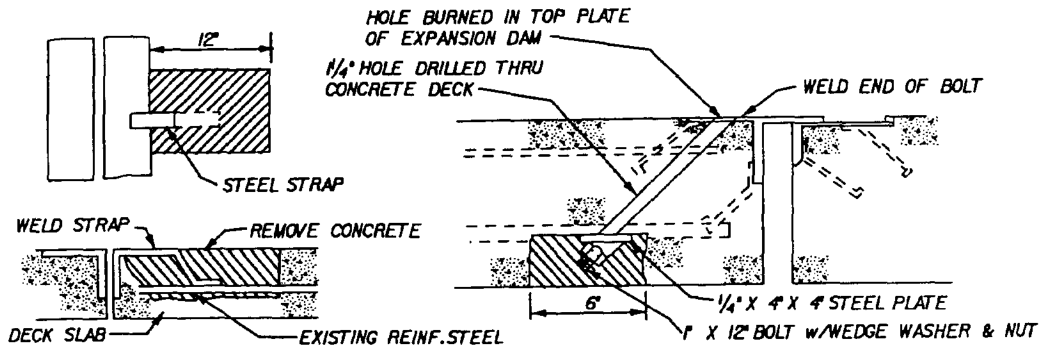
(1) *Open armored joint.* This repair method can be used to spot repair a loose expansion dam or across the full length of armored, finger, and sliding joints. The repair involves removing a small portion of concrete, welding a steel strap to the dam and the deck's reinforcing steel, and replacing the concrete (figure 13-10, part a). The procedure is as follows. Identify the loose portions of the expansion joints requiring repair. Mark 12- by 8-inch rectangles immediately adjacent to the dam on 18-inch centers, and saw cut around the perimeter of the rectangle to a l-inch depth. Remove the concrete inside the rectangle to a depth required to expose the deck's reinforcing steel with an air hammer. Cut a slot 1 inch wide into the dam and weld a ¼- by l- by 12-inch steel Z-strap into the slot and to the deck's reinforcing steel. Sandblast the rectangular opening in the concrete and blow out all debris. Apply an epoxy bonding compound to the exposed concrete and fill the rectangle with a compacted latex modified portland cement concrete.

(2) *Sliding joint.* This repair can also be used on armored and finger joints. The repair places l-inch diameter bolts on 2-foot centers through the bridge deck and the bolt is welded to the expansion dam. The bolt is anchored to the bottom of the deck with a steel plate, wedge washer, and nut (figure 13-10, part b). The repair procedure is as follows. Burn holes through the top flange of the expansion dam on 2-foot centers across the area to be repaired. Below the holes in the top flange, drill 1¼-inch hole through the deck at a 45-degree angle. Saw cut a 6- by 6-inch area, 1 inch deep around the exit of the drilled hole on the underside of the deck. Remove the concrete inside the scored area to the reinforcing steel. Place a l-inch-diameter bolt through the hole in the flange and the deck. Cut the head of the bolt flush with the top flange and weld to the flange with a full penetration weld. The bolt should extend through




END DAM SYSTEM FOR
END BENT JOINT SEALS

*Figure 13-9. Placing an elastomeric seal in an asphalt overlay.*




A. WELDED Z-STRAP REPAIR. B. ANCHOR BOLT REPAIR.

*Figure 13-10. Expansion dam repairs.*

the deck. Place a ½-inch-thick layer of latex modified concrete in the drilled hole around the bottom of the bolt. Position a ¼- by 4- by 4-inch steel plate with a 1¼-foot hole, add the wedge washer (45-degree wedge) and nut, then tighten. Apply an epoxy bonding compound to the 6- by 6-inch area and fill with latex modified concrete. Drill and tap the flange close to the bolt location and install a zerk fitting. Pump epoxy through the fitting to fill the voids under the expansion dam and around the bolt. Remove the zerk fittings and weld the hole closed. Grind the top flange smooth.

## 13-9. Abutments and wingwalls

The concrete in abutments and wingwalls may deteriorate from the effects of water, deicing chemicals, freeze cracking, or impact by debris which results in breaking off the edges or portions of the face. These conditions require that repairs be made to prevent continued deterioration, particularly increased spalling due to moisture reaching the rebar and causing corrosion. The following steps in the rehabilitation procedure are normally required (figures 13-11 and 13-12). Establish traffic control, as necessary. Excavate as required to set dowels and forms. Remove deteriorated concrete by chipping and blast cleaning. Drill and set tie screws and log studs to support the form work. Set reinforcing steel and forms. Apply epoxy-bonding agent to the concrete surface. Place concrete, cure, and remove forms. Install erosion control material as necessary.

## 13-10. Bridge seats

Problems often found in concrete bridge seats include deterioration of concrete, corrosion of the reinforcing bars, friction from the beam or bearing devices sliding directly on the seat, and the improper design of the seat which results in shear failure. During the preliminary planning stage,

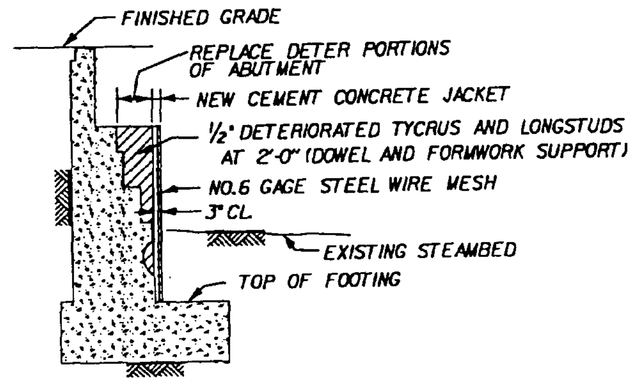



*Figure 13-11. Repair of abutment and wingwall faces using a jacket.*

the specific cause of the problems should be determined to properly repair the damage. A detailed plan of the jacking requirements should be made. Several repair procedures are as follows:

*a. Abutment and cap seats (figure 13-13).* Remove traffic from structure during jacking operations. Lift jacks in unison to prevent a concentration of stress in one area and possible damage to the superstructure. Restrict vehicle traffic during the repair as much as possible. Saw cut around concrete to be removed and avoid cutting reinforcing steel. Remove deteriorated concrete to the horizontal and vertical planes ensuring that sound concrete is exposed. Add reinforcing steel as required and construct forms to confine the new concrete. Apply bonding material to the prepared surface that will interface with the new concrete. Place and cure new concrete. Service, repair, or replace bearings as necessary.

*b. Concrete cap extension.* This repair restores adequate bearing for beams that deteriorated or sheared at the point of bearing by anchoring an extension to the existing cap. The procedure is as follows (figure 13-14). Locate and drill 6-inch-deep holes to form a grid in the existing cap and install

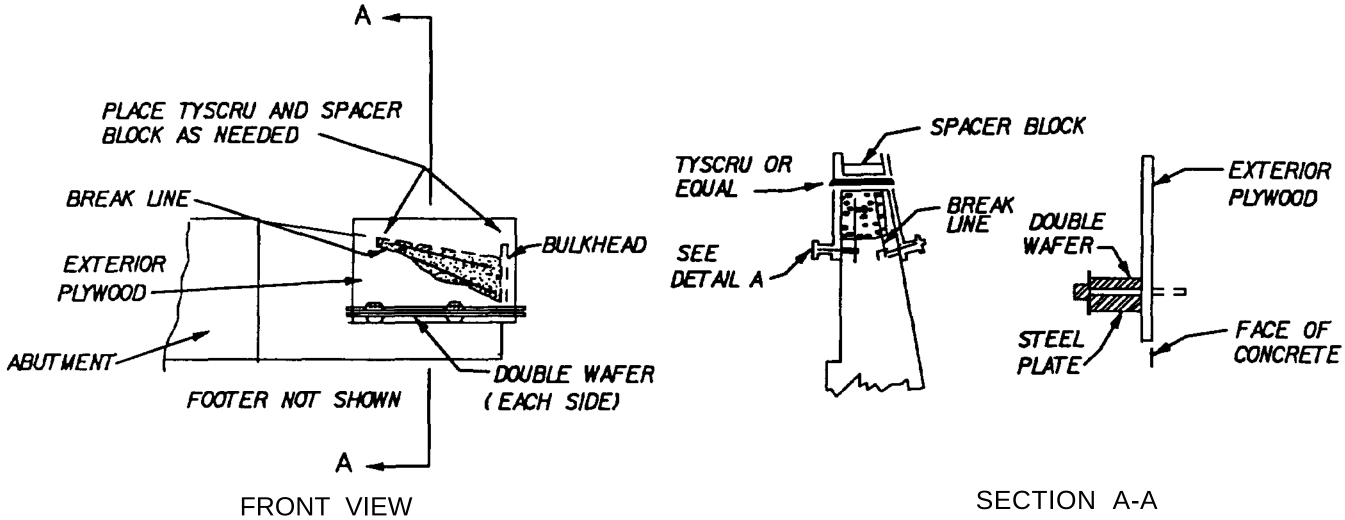



*Figure 13-12. Repair of broken or deteriorated wingwalls.*

concrete anchors that will accept a ¾-inch bolt. Place ¾- by 9-inch bolts 4 inches into the concrete anchors. Wire a reinforcing steel (No. 4 bars) grid to the inside head of the anchor bolts. Construct a form around the reinforcing steel grid with a minimum of 4 inches cover around the sides of the bolts and a minimum of 2 inches cover for the face of the extension. Place roofing paper against the bottom of the beam and place Class IV concrete in the form. Remove forms after 3 days. The extension should not carry any load during curing. Repair any damage to the end of the beam.

*c. Beam saddle.* The saddle restores bearing for beams and caps where they have deteriorated or been damaged in the bearing area. The procedure is as follows (figure 13-15). Obtain measurements of the cap and beam width, and have an engineer design the saddle. Prepare the top of the cap and the beams for good bearing contact with the saddle. Use neoprene bearing pads for contact points between the saddle and the beam and cap. Place saddle members in contact with the cap across the cap on each side of the beam. Drop one bolt through a hole at each end of the two saddle cap contact members, and bolt the saddle bearing members in place under the beam. Place neoprene bearing pads under the beam, and tighten the bolts in place. Install and tighten the remaining bolts.

## 13-11. Columns and piles

The typical repair involving concrete columns and piles is to place a concrete jacket around the member to protect it from further deterioration or to restore the structural integrity of the member. The repair can be made with a standard wood or metal form work which is removed after curing or a fiberglass form that remains in place and helps protect the surface of the member.

*a. Standard formwork.* This repair method is used for piles that have been damaged or deteriorated to the point that structural integrity of the member is in question. In this procedure, the pile is encased with a concrete jacket reinforced with epoxy coated reinforcing steel (figure 13-16). The construction procedure is as follows. Remove all deteriorated concrete to a sound base. Clean the pile to ensure proper bonding with the jacket. Sand-blast rebars to remove corrosion and rust. Place a rebar cage around the pile to reinforce the pile. Treat the inside face of the forms with a release agent, and set the forms for the concrete jacket around the rebar cage and pile. Dewater the forms and place Class III concrete. Allow a minimum of 72 hours for curing.

*b. Fiberglass forms.* These forms can be used to prevent further deterioration or restore structural integrity to piles and columns. The repair involves the encasement of the pile or column in the fiberglass form and filling the form with epoxy grout, cement grout, or Class III concrete. The fiberglass forms should be a minimum of 1/8-inch in thickness with noncorrosive standoffs and a compressible sealing strip at the bottom. Installation procedures will vary depending upon the degree and location of damage and the specific jacket manufacturer's recommendations. The basic

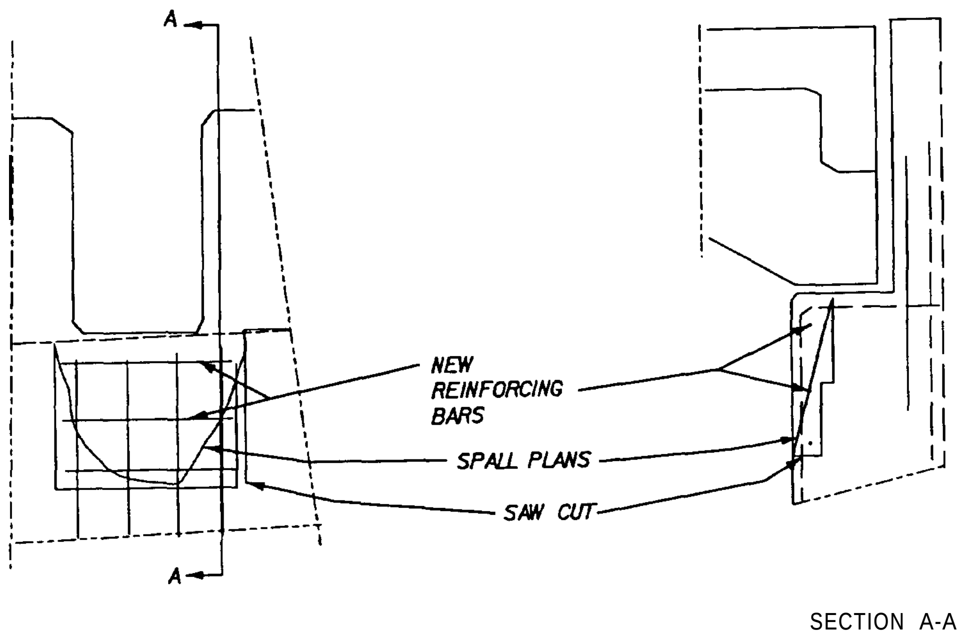



*Figure 13-13. Typical repair of concrete bridge seats.*

procedure for using fiberglass forms is as follows. Clean pile surfaces of materials which prevent bonding. Remove deteriorated concrete down to a sound concrete base. Sandblast exposed rebar to a "near-white metal" finish. Place the jacket form work around the pile. The form should have built in standoffs, concrete blocks attached to the inside face, or double-nut bolts placed through drilled holes to provide the proper standoff. Seal the form's joints and bottom with an epoxy compound. Place external bracing and bonding materials to help prevent form movement and bulging. Dewater form and fill the space between the pile and form with the appropriate tiller. Cure, remove external bracing and banding, and clean any filler material from the form's faces.

## 13-12. Stringers and beams

Spall in beams can be dealt with in a similar manner as walls by constructing a form around the damaged area and replacing the lost concrete (paragraph 13-10a). Shotcrete is an excellent material to use in this type of repair. The major problem caused by concrete deterioration is the loss of effective reinforcing bar diameter due to corrosion. This is also true of cracks which allow water to penetrate to the reinforcing steel. Due to the criticality of reinforcing bars in beams, it is important to repair or replace any damaged reinforcing bars. There are three methods available to reestablish the reinforcing steel required for proper beam performance:

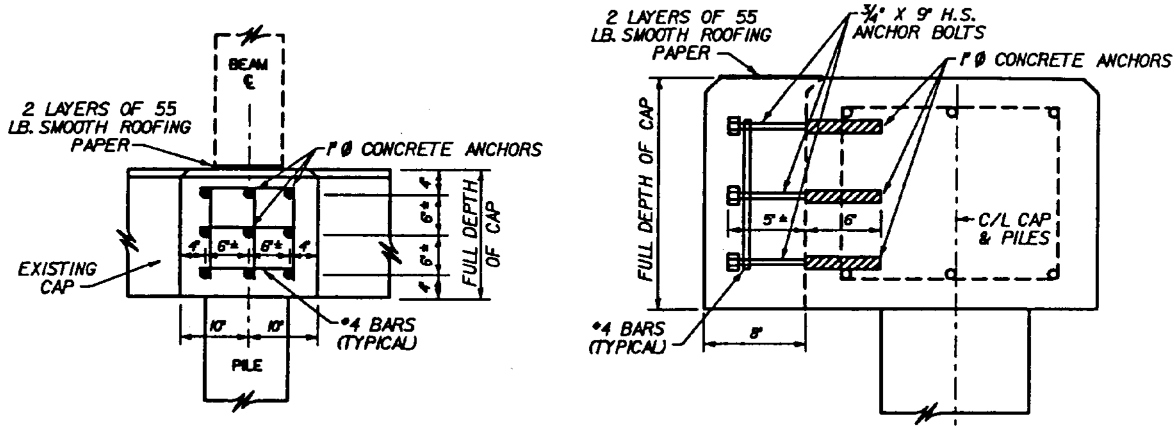
*a. Conventional repair.* Refer to paragraph 13-7.

*b. Conventional reinforcement.* Refer to paragraph 13-6a.

*c. Prestressing steel.* This method can be used to close a crack and/or provide external reinforcing steel to support the beam loading (figure 13-17). Install as follows. Clean the crack and any exposed rebar. Drill holes through the side of the beam (missing existing rebar) for the prestressing anchor at both ends of the beam. Install anchors on both sides and at both ends of the beam by running bolts through prepared holes in the anchors and beam. The anchor should be designed by an engineer and generally consist of a reinforced angle section with holes in the flanges to receive the through bolts and the tension tie. Connect the tension tie to each set of anchors on either side of the beam. Apply tension to the ties using a turnbuckle or torquing nuts. Tension should be applied across both sides of the beam evenly. Increase tension until the crack closes and seal with a flexible seal. This method can also be used in conjunction with a patch to replace deteriorated steel.

## 13-13. Decks

*a. Spall.* Spa11 repair on bridge decks can be broken into three categories based on the overall condition of the deck, as is shown further into this paragraph. The categories are identified according to the amount of spall, the extent of total deterioration (spall, delaminations, and corrosion poten-




**a. FRONT VIEW OF CAP EXTENSION** **b. CROSSSECTION OF CAP EXTENSION**

*Figure 13-14. Concrete cap extension to increase bearing surfaces.*

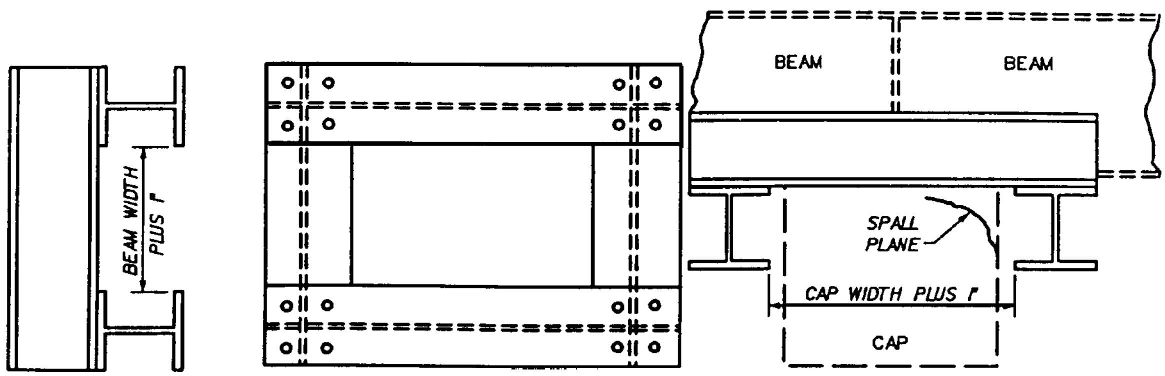



*Figure 13-15. Typical beam saddle design using standard steel W-sections.*

tials over -0.35 volts), and total percentage of concrete samples containing at least 2 pounds of chloride per cubic yard of concrete:

(1) Extensive active corrosion.

*(a)* Spall covers more than 5 percent of total deck area.

*(b)* Deterioration covers more than 40 percent of total deck area.

*(c)* Chlorides high in over 40 percent of samples.

(2) Moderate active corrosion.

*(a)* Spall covers from 0 to 5 percent of total deck area.

*(b)* Deterioration covers from 5 to 40 percent of total deck area.

*(c)* Chlorides high in 5 to 40 percent of samples.

(3) Light to no active corrosion.

*(a)* No spall present.

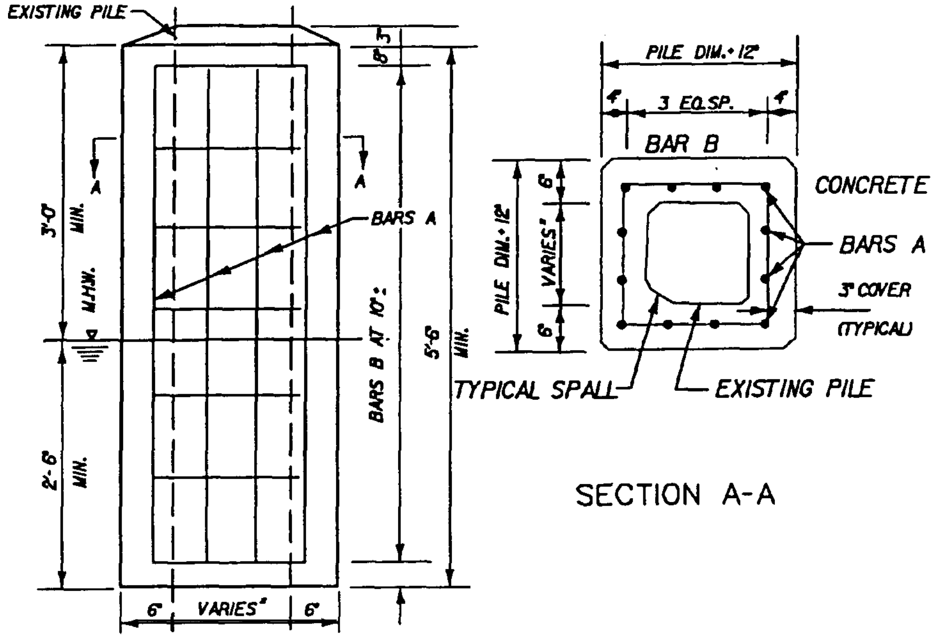



*Figure 13-16. Standard concrete pile jacket with steel reinforcing cage.*

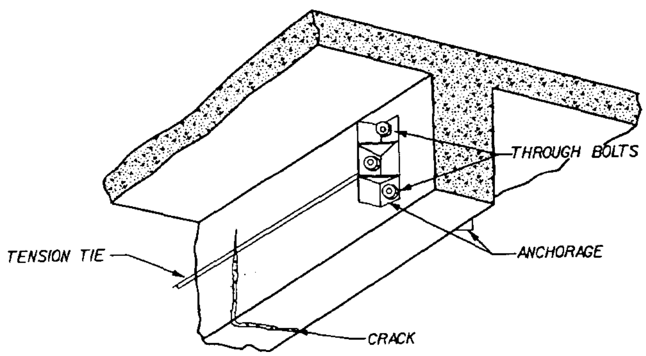



*Figure 13-17. External prestressing strands used to close a crack.*

*(b)* Deterioration covers from 0 to 5 percent of total deck area.

*(c)* Chlorides high in from 0 to 5 percent of samples.

In many cases the identifying characteristics of the moderate category will overlap with the other two categories, and a best judgment based on engineering, economics, and other factors must be used to establish the appropriate repair for the bridge. The deck repair procedures for each of these categories are outlined in table 13-2.

*b. Cracks.* Cracks in decks can be repaired as discussed in paragraph 13-6. In composite deck systems, prestressing techniques can be employed to help close cracks in the deck. The repair

*Table 13-2. Bridge deck restoration procedures*

| Bridge Deck Restoration | Bridge Deck Deterioration | | | | | |
|---|---|---|---|---|---|---|
| | Light | | Moderate | | Extensive | |
| | Extend Life 10-15 years | Extend Life > 15 years | Extend Life 10-15 years | Extend Life > 15 years | Extend Life 10-15 years | Extend Life > 15 years |
| Remove and replace all areas of deterioration and chloride contaminated concrete. | | X | | | | |
| Remove all deteriorated concrete. Replace concrete in accordance with the selected protective system (see below). | X | | X | X* | X | |
| Replace the entire deck. | | | | X* | | X |
| Protective Systems | | | | | | |
| Membrane w/bc overlay. | X | X | X | X | X | X |
| Latex modified concrete overlay. | X | X | X | X | X | X |
| Cathodic protection. | X | X | X | X | X | X |
| Epoxy coated rebars. | | | | X* | | X |

* Conduct a cost analysis to determine the most economical repair option.

consists of placing a tie rod across the deck crack. The tie rod is emplaced through drilled holes in the beams on either side of the cracked deck. The torquing nuts or turnbuckles on the tie rods are then tightened to close the crack in the deck (figure 13-18).

### 13-14. Replacement of concrete members

*a. Decks.* After the deteriorated portion of the deck has been removed, replacement decks can be cast in place or precast sections can be fixed into position. The advantage to using precast sections is that no form work is required, and smaller portions of the deck can be removed and replaced, thereby minimizing traffic disruption. The procedures for both types of deck replacement are outlined:

(1) *Cast in place.* Remove the deteriorated deck. Construct the form work for the new deck. Shore the form work to carry the dead load of the deck. Install reinforcing steel. Place the concrete and allow to cure long enough to achieve its design strength.

(2) *Precast.* Remove the deck area to be replaced with the precast section. Place the precast sections with a crane, being careful to overlap extended rebar when placing adjacent panels and wire together. Form around the connection between adjacent panels and apply an epoxy agent to interface between the sides of the panels and the new concrete.

*b. Piles.* Piles which cannot be jacketed can be replaced in much the same manner as timber piles (chapter 12).

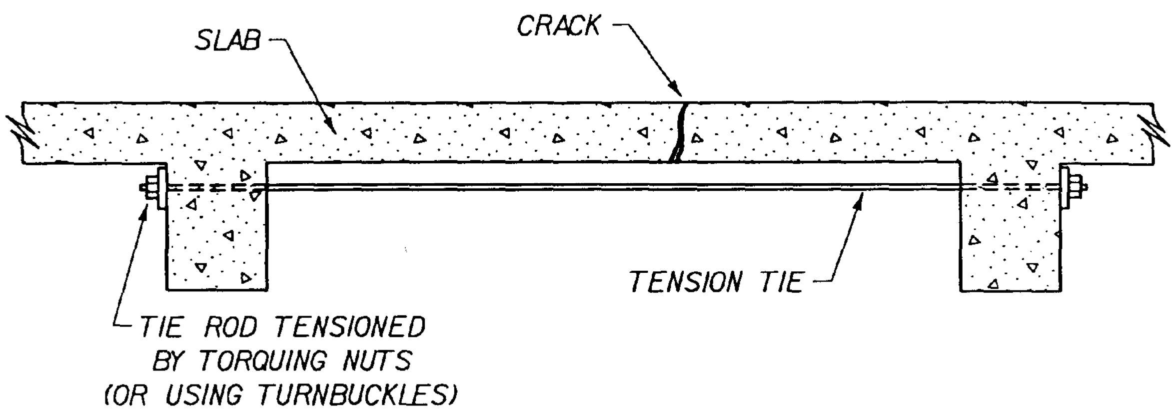



*Figure 13-18. Closing a crack in a deck using prestressing steel.*

## Section III. UPGRADE CONCRETE BRIDGES

### 13-15. General upgrade methods

*a. Substructure upgrade.* The strength of the substructure can be increased by adding piles/columns to the pier or by placing a concrete jacket around the existing piles.

(1) *Jacketing (figure 13-19, part a).* The jacketing procedures for strengthening columns and piles are basically the same as the repair procedures discussed in section II of this chapter. For strengthening, the jacket must be extended the full length of the column and connected to the cap and footing. The jacket is connected to the existing cap and footing by grouting dowels into drilled holes.

(2) *Jacketing with spiraled reinforcement (figure 13-19, part b).* This method is used to improve the lateral strength of circular columns. It involves wrapping tensioned prestressing wire around the existing column or applying a series of M-inch-diameter reinforcing bar hoops with turnbuckles at each end to pretension the hoops. A cover of shotcrete or cast-in-place concrete is then applied to the reinforcing steel.

(3) *Partial jacketing (figure 13-19, part c).* This technique involves attaching precast sections to the existing column using bolts or the casting of any additional reinforced concrete to the existing column that does not completely encase the column.

*b. Span reduction.* The common methods of shortening spans discussed in chapter 10 also apply for concrete bridges. These methods include intermediate piers, A-frames, or knee braces.

*c. Posttensioning.* All the posttensioning techniques shown in table 10-3 can be applied to concrete bridges. The connections and components for these systems should be designed by a structural engineer.

*d. Add stringers.* Additional concrete stringers can be cast in place under the deck and connected to the deck with dowels. The added dead load may reduce the benefit of the additional stringers and may prove uneconomical to construct. Another alternative is the addition of steel stringers between each of the existing concrete stringers. The abutments and caps can have seats constructed on them for the steel members.

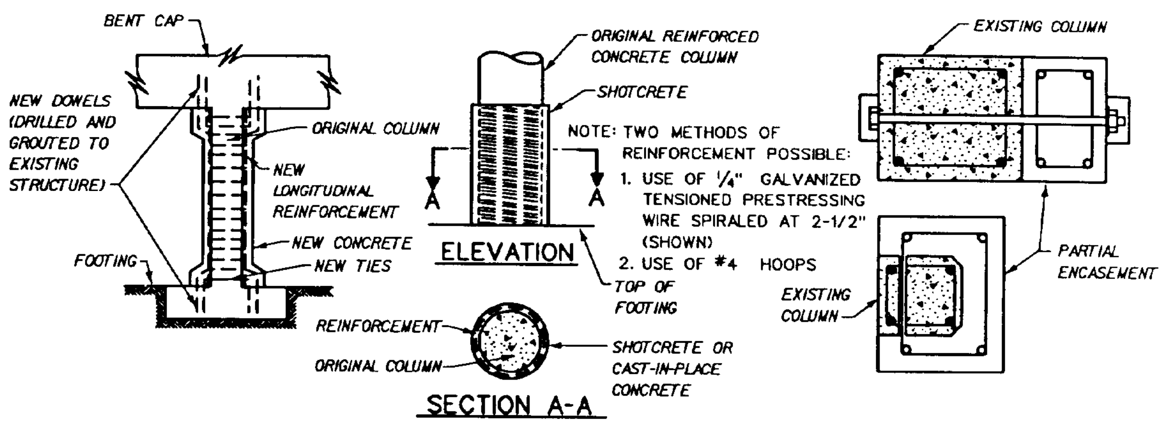
## 13-16. Strengthen individual members

Individual concrete members can be strengthened by jacketing, inserting reinforcing bars, prestressing, or by external reinforcement. Members are generally strengthened to counter increases in shear or flexural forces.

*a. Shear reinforcement of beams.*

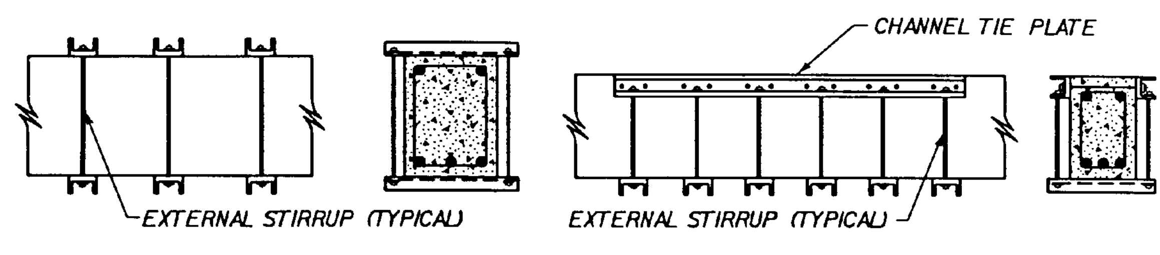
(1) *External reinforcement (figure 13-20).* Install external reinforcement as follows. Run channel sections across the top of the beam or attach channel sections to either side of the upper portion of the beam using through bolts in drilled holes. Run channel sections across the bottom of the beam and place tie rods through prepared holes in the top and bottom channels. Use torque nuts on either end of the rods to prestress the rods. The prestressed rods installed at specified spacings provide an increase in the shear capacity of the beam.

(2) *Reinforcing bar insertion (figure 13-2).* Insert bars as follows. Seal all cracks with silicone rubber. Mark the girder centerline on the deck. Locate the transverse deck reinforcement. Drill 45-degree holes avoiding the reinforcing bars. Pump epoxy into the holes and cracks, and insert the reinforcing bars into the epoxy-filled holes.




a. STANDARD TECHNIQUE b. SPIRAL REINFORCEMENT c. PARTIAL JACKETING

*Figure 13-19. Jacketing of concrete columns.*




a. ADDITION OF EXTERNAL STIRRUPS

b. ATTACHMENT OF VERTICAL STIRRUPS USING STEEL SECTIONS AS SIDE MEMBERS

*Figure 13-20. External shear reinforcement for concrete beams.*

*b. Shear reinforcement of box beams.*

(1) *External reinforcement (figure 13-21).* Install as follows. Drill holes for the tendons through or just outside the web of the box beam. Counter sink the drill holes. Install the prestressing tendons. Inject epoxy into any existing cracks. Tighten the nuts on the tendon to prestress the beam, carefully following design specifications to avoid overstressing the beam. Inject epoxy around the tendons, and dry pack the countersink holes flush with the concrete surface.

(2) *Web reinforcement (figure 13-22).* Install as follows. Locate and drill holes on the inside face of the web of the box-beam. Clean the holes of dust and debris, and set concrete anchors in place. Place anchor bolts with a spacer and steel plate attached. Weld rebar to the steel plate on either side of the bolt. Attach horizontal reinforcing bars to the vertical rebar.

*c. Flexural reinforcement of beams.* The two most common methods of strengthening concrete beams in flexure are adding steel cover plates to the beam's tension face and partial encasement of the beam in reinforced concrete.

(1) *Steel channel cover plate (figure 13-23).* Install as follows. Remove dirt and any foreign material, sand blast, and then remove any debris with compressed air. Locate the beam's stirrups and longitudinal steel. Mark the location of the drill holes to miss the reinforcing steel and still be above the bottom row of longitudinal steel. Drill holes through the concrete beam. Drill or cut holes in the steel channel to match the holes in the beam. Position the channel into place and install bolts to hold it in place. Inject epoxy resign into the remaining holes and install the bolts. Take out the positioning bolts, inject epoxy, and reinstall. Seal between the channel and the concrete beam.

(2) *Partial jacketing.* The purpose of the jacketing in this case is to provide cover for the additional reinforcing bars which are positioned to help carry the flexural load. The longitudinal

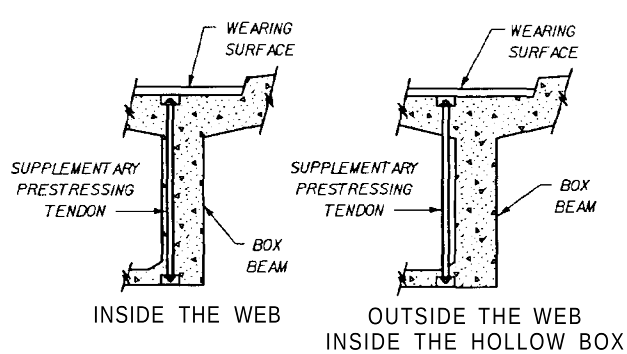



*Figure 13-21. Reinforcing boxbeams for shear.*

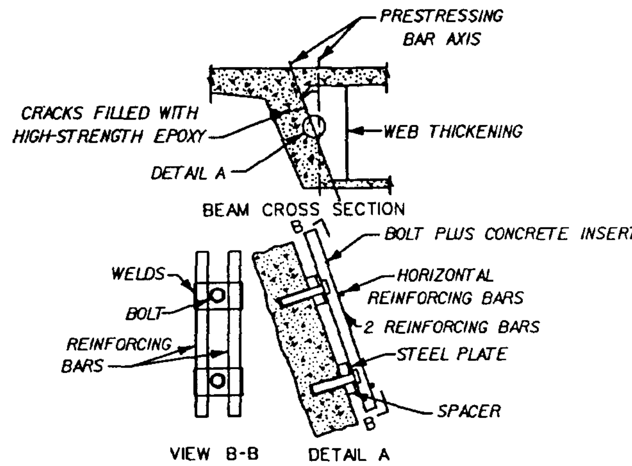



*Figure 13-22. Web reinforcement of boxbeams.*

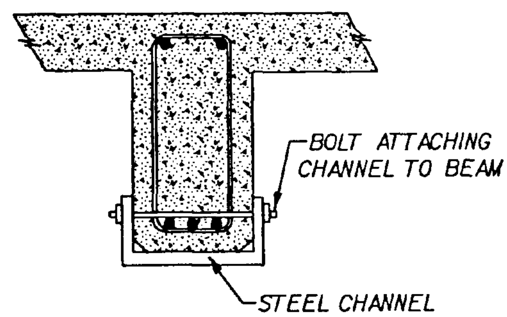



*Figure 13-23. Steel channel used to reinforce beams*

reinforcing bars are held in place by the vertical bars that are attached to the existing beam (figure 13-24, part a), placed through the beam (figure 13-24, part b), or run through the existing deck (figure 13-25, part c). The concrete cover can be cast in place or shotcreted.

(3) *External plates.*

*(a)* This method involves bonding mild steel plates to the concrete member. This composite system relies on the effectiveness of the bonds between the concrete/adhesive and the adhesive/steel surfaces. This technique should not be used on members with reinforcement corrosion or high concentrations of chloride ions.

*(b)* Design considerations to avoid brittle cracking of the concrete cover are as follows: use steel plates with a minimum width/thickness ratio of 40 to reduce horizontal shears; limit the nominal elastic horizontal shear stress in the adhesive to the tensile capacity of the concrete for an applied safety factor.

*(c)* This strengthening method should be conducted by trained personnel using the following procedure. Clean and sandblast the steel plates and apply an epoxy primer paint adhesive. Sand

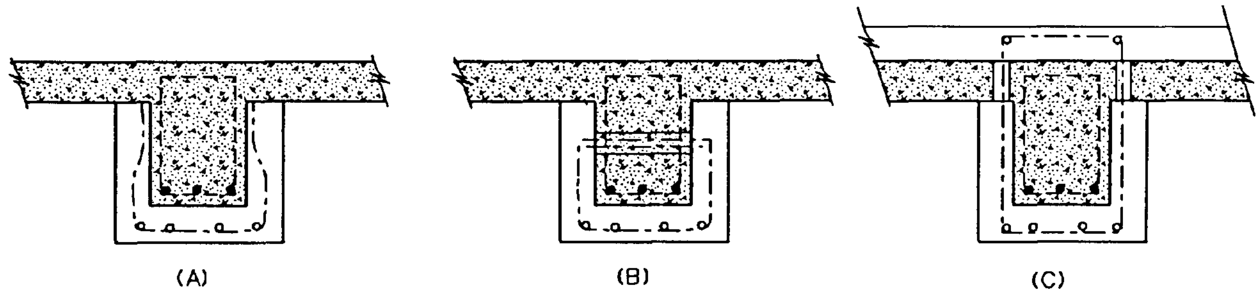



*Figure 13-24. Concrete beams reinforced with concrete sleeves.*

blast the concrete to remove the surface laitance and to expose coarse aggregates. Drill holes in the slab or beam to emplace anchor bolts for the ends of the steel plates. Mix adhesive and apply to the steel plate with a thickness between 1/16th to 1/8th inch. The adhesive should be thicker along the centerline of the plate to prevent air pockets from forming between the plate and concrete faces. Place the steel plate on the underside of the beam or slab and bolt the ends to hold into place. Supplemental bolting is used at the plate ends to reduce peel failures and hold the plate in place in case of failure. Apply pressure along the full length of the plate using secondary supports and wedges. Tighten the end bolts into place and allow the adhesive to cure (normally 24 hours). Remove secondary supports and paint the steel plate.

## 13-17. Prestressed concrete members

By design, prestressed concrete members behave differently than conventionally reinforced members. As a result, many of the methods discussed in the preceding paragraphs do not apply to prestressed concrete members. Due to its complexity, the repair of prestressed concrete members is not covered in this manual. The following reports by the Transportation Research Board should be referred to for the evaluation and repair of prestressed concrete members:

(1) National Cooperative Highway Research Program (NCHRP) Report Number 226, "Damage Evaluation and Repair Methods for Prestressed Concrete Bridge Members."

(2) NCHRP Report Number 280, "Guidelines for Evaluation and Repair of Prestressed Concrete Bridge Members."

# APPENDIX A

# REFERENCES AND BIBLIOGRAPHY

## A-1. References

### Government Publications

**Departments of the Army, Navy, and Air Force**

| | |
|---|---|
| AR 420-72 | Surfaced Areas, Bridges, Railroad Track and Associated Appurtenances |
| FM 5-446 | Military Nonstandard Fixed Bridging |
| TM 5-628 | Railroad Track Standards |
| FM 5-277 | Bailey Bridge |

**Coast Guard**

| | |
|---|---|
| Pamphlet CG204 | Aids to Navigation |

**Department of Transportation, Federal Highway Administration**

Bridge Inspector's Training Manual 70
Inspection of Fracture Critical Bridge Members

### Nongovernment Publications

**American Association of State Highway Transportation Officials (AASHTO), 444 North Capitol Street, Washington, DC 20001**

Standard Specifications for Highway Bridges, Fourteenth Edition, 1989
Manual on Uniform Traffic Control Devices
Manual for Maintenance Inspection of Bridges

**National Cooperative Highway Research Program (NCHRP), Transportation Research Board, National Research Council, Washington, DC**

| | |
|---|---|
| Report 280 | Guidelines for Evaluation and Repair of Prestressed Concrete Bridge Members, December 1985 |
| Report 293 | Damage Evaluation and Repair Methods for Prestressed Concrete Bridge Members, November 1980 |

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### Manuals

*AASHTO Maintenance Manual, 1987*. American Association of State Highway and Transportation Officials, Washington, DC (1987).

*AASHTO Manual for Bridge Maintenance, 1987*. American Association of State Highway and Transportation Officials, Washington, DC (1987).

*American Concrete Institute (ACI) Manual of Concrete Practice,* 1988. American Concrete Institute, Detroit, MI.

*Annual Book of American Society for Testing and Materials (ASTM) Specification*, 1990. American Society for Testing and Materials, 1961 Race Street, Philadelphia, PA.

*Guide Specifications for Strength Evaluation of Existing Steel and Concrete Bridges,* 1989. American Association of State Highway and Transportation Officials, Washington, DC (1989).

*Guide Specifications for Fracture Critical Non-Redundant Steel Bridge Members*, 1978. American Association of State Highway and Transportation Officials, Washington, DC (1989).

*Manual for Railway Engineering*, American Railway Engineering Association (AREA), Washington, DC (1989).

*Manual for Bridge Maintenance Planning and Repair Methods*, Volume I. Florida Department of Transportation, State Maintenance Office.

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| | |
|---|---|
| FM 5-742 | Concrete and Masonry |
| FM 5-551 | Carpentry |
| TM 5-744 | Structural Steel Work |
| TM 5-622/MO-104/AFM 91-34 | Maintenance of Waterfront Facilities |

Reports

National Cooperative Highway Research Program, Report 293. “Methods of Strengthening Existing Highway Bridges.” Transportation Research Board, National Research Council, Washington, DC, September 1987.

National Cooperative Highway Research Program, Report 333. “Guidelines for Evaluating Corrosion Effects in Existing Steel Bridges.” Transportation Research Board, National Research Council, Washington, DC, December 1990.

Journal Articles

American Concrete Institute Committee 201, “Guide to Durable Concrete,” *Journal of the American Concrete Institute*, Number 12, Proceedings Volume 74, pages 573-609, December 1977.

# APPENDIX B

# SUGGESTED ITEMS FOR ARMY ANNUAL AND AIR FORCE BIANNUAL BRIDGE INSPECTIONS

## BRIDGE INSPECTION ITEMS

Include the following items:

1. Installation.
2. Bridge number.
3. Location.
4. Date inspected.
5. Existing bridge classification (if applicable).

For the following components, address each appropriate inspection item and make notes of any observed deficiencies and recommendations:

A. Timber Abutments

1. Signs of settlement.
2. Rusting of steel rods.
3. Decay of end dam, wingpost, post, and/or cap.
4. Deterioration of block (bearing and anchor).
5. Decay of sill and footing.
6. Loose timbers.
7. Decay of breakage of piles (wing or bearing).

B. Steel Pile Abutments

1. Settlement.
2. Rusting of end dam, pile and/or cap.
3. Section loss of steel members.
4. Missing, loose, or rusting bolts.

C. Concrete Abutments, Wingwalls, and Retaining Walls

1. Settlement.
2. Proper function of weep holes.
3. Cracking or spalling of bearing seats.
4. Deterioration of cracking of concrete.
5. Exposed reinforcing steel.

D. Timber Piers and Bents

1. Settlement.
2. Decay of caps, bracing, scabbing, or corbels.
3. Missing posts or piles.
4. Decay of posts or piles.
5. Debris around or against piers.
6. Section loss of sills or footings.
7. Erosion around piers.
8. Rusting of wire-rope cross bracing.
9. Loose or missing bolts.
10. Splitting or crushing of the timber when:
    *a.* The cap bears directly upon the cap, or
    *b.* Beam bears directly upon the cap.
11. Excessive deflection or movement of members.

E. Steel Piers and Bents

1. Settlement or misalignment.
2. Rusting of steel members or bearings.

3. Debris.
4. Rotation of steel cap due to eccentric connection.
5. Braces with broken connections or loose rivets or bolts.
6. Member damage from collision.
7. Need for painting.
8. Signs of excessive deflection or movement of members.

F. Concrete Piers and Bents
1. Settlement.
2. Deterioration or spalling of concrete.
3. Cracking of pier columns and/or pier caps.
4. Cracking or spalling of bearing seats.
5. Exposed reinforcing steel.
6. Debris around piers or bents.
7. Section loss of footings.
8. Erosion around piers.
9. Collision damage.

G. Concrete (girders, beams, frames, etc.)
1. Spalling (give special attention to points of bearing).
2. Diagonal cracking, especially near supports.
3. Vertical cracks or disintegration of concrete, especially in the area of the tension steel.
4. Excessive vibration or deflection during vehicle passage.
5. Corrosion or exposure of reinforcing steel.
6. Corroded, misaligned, frozen, or loose metal bearings.
7. Tearing, splitting, bulging of elastomeric bearing pads.

H. Timber (trusses, beams, stringers, etc.)
1. Broken, deteriorated, or loose shear connectors.
2. Failure, bowing, or joint separation of individual members of trusses.
3. Loose, broken, or worn planks on the timber deck.
4. Improper functioning of members.
5. Rotting or deterioration of members.

I. Steel (girders, stringers, floor beams, diaphragms, cross frames, portals, sway frames, lateral bracing, truss members, bearing and anchorage, eyebars, cables, and fittings)
1. Corrosion and deterioration along:
   a. Web flange.
   *b.* Around bolts and rivets heads.
   *c.* Under deck joints.
   *d.* Any other points which may be exposed to roadway drainage.
   *e.* Eyebars, cables, and fittings.
2. Signs of misalignment or distortion due to overstress, collision, or fire.
3. Wrinkles, waves, cracks, or damage in the web and flange of steel beam, particularly near points of bearing.
4. Unusual vibration or excessive deflection occurring during the passage of heavy loads.
5. Frozen or loose bearings.
6. Splitting, tearing, or bulging in elastomeric bearing pads.

J. Concrete Appurtenances
1. Cracking, scaling, and spalling on the:
   *a.* Deck surface.
   *b.* Deck underside.
   *c.* Wearing surface (map cracking, potholes, etc.).

*NOTE: If deterioration is suspected, remove a small section of the wearing surface in order to check the condition of the concrete deck.*

2. Exposed and/or rusting reinforcing steel.
3. Loose or deteriorated joint sealant.

4. Adequacy of sidewalk drainage.
5. Effect of additional wearing surfaces on adequacy of curb height.

K. Timber Appurtenances

1. Loose, broken, or worn planks.
2. Evidence of decay, particularly at the contact point with the stringer where moisture accumulates.
3. Excessive deflection or loose members with the passing of traffic.
4. Effect of additional wearing surfaces on adequacy of curb height.

L. Steel Appurtenances (including but not limited to decks, gratings, curbs, and sidewalks)

1. Corroded or cracked welds.
2. Slipperiness when deck or steel sidewalk is wet.
3. Loose fasteners or loose connections.
4. Horizontal and vertical misalignment and/or collision damage.

M. Masonry Bridges

1. Settlement.
2. Proper function of weep holes.
3. Collision damage.
4. Spalling or splitting of rocks.
5. Loose or cracked mortar.
6. Plant growth, such as lichens and ivy, attaching to stone surfaces.
7. Marine borers attacking the rock and mortar.

N. Miscellaneous

1. Existence and appropriateness of bridge classification signs.
2. Condition of approachments.
3. Leaks, breaks, cracks, or deterioration of pipes, ducts, or other utilities.
4. Damaged or loose utility supports.
5. Wear or deterioration in the shielding and insulation of power cables.

# APPENDIX C

# SUGGESTED ITEMS FOR ARMY TRIENNIAL AND EVERY THIRD AIR FORCE BIANNUAL BRIDGE INSPECTIONS

## BRIDGE INSPECTION ITEMS

Include the following items:

### A. General Information to Include

1. Bridge name.
2. Location.
3. Date of inspection.
4. Design load (if known).
5. Military load classification (if known).
6. Date built.
7. Traffic lanes.
8. Transverse section (describe or sketch).
9. Structure length.
10. No. of spans.
11. Plans available.
12. Inspection records.
    *a.* Year inspected.
    *b.* Inspector.
    *c.* Qualification.
13. Bridge description.
    *a.* Floor system.
    *b.* Beams.
    *c.* Girders.
    *d.* Stringers.
    *e.* Trusses.
    *f.* Suspension.
    *g.* Piers.
    *h.* Abutment A.
    *i.* Abutment B.
    *j.* Foundation.
    *k.* Piers or bents.
        (1) Caps.
        (2) Posts or columns.
        (3) Footings.
        (4) Piles.
        (5) Other.
    *l.* Deck:
        (1) Wearing surface.
        (2) Curb.
        (3) Railings.
        (4) Sidewalk.
        (5) Other.

### B. Bridge Components Rating Information

The following items may be rated using the suggested ratings from part C of this appendix. Descriptive remarks may also be included.

1. Traffic safety features.
    *a.* Bridge railing.

*b*. Transitions.
*c*. Approach guardrail.
*d*. Approach guardrail terminal.

2. Deck.
*a*. Wearing surface.
*b*. Deck structural condition.
*c*. Curbs.
*d*. Median.
*e*. Sidewalk.
*f*. Parapet.
*g*. Railings.
*h*. Drains.
*i*. Lighting.
*j*. Utilities.
*k*. Expansion joints.

3. Load bearing components.
*a*. Bearing devices.
*b*. Stringers.
*c*. Girders or beams.
(1) General.
(2) Cross frames.
(3) Bracing.
*d*. Floor beams.
*e*. Trusses.
(1) General.
(2) Portals.
(3) Bracing.
*f*. Paint.

4. Abutments.
*a*. Wings.
*b*. Backwall.
*c*. Bearing seats.
*d*. Breast wall.
*e*. Weep holes.
*f*. Footing.
*g*. Piles.
*h*. Bracing.
*i*. Erosion or scour.
*j*. Settlement.

5. Piers/bents or pile bents.
*a*. Caps.
*b*. Bearing seats.
*c*. Column, stem, or wall.
*d*. Footing.
*e*. Piles.
*f*. Bracing.
*g*. Erosion or scour.
*h*. Settlement.

6. Channel and channel protection.
*a*. Channel scour.
*b*. Embankment erosion.
*c*. Drift.
*d*. Vegetation.
*e*. Fender system.
*f*. Spur dikes and jetties.

*g*. Rip rap.
*h*. Adequacy of opening.
7. Approach.
*a*. Alignment.
*b*. Approach.
*c*. Relief joints.
*d*. Approach.
(1) Guardrail.
(2) Pavement.
(3) Embankment.

C. Suggested Component Ratings

1. Traffic Safety Features.

| *Code* | *Description* |
|---|---|
| 0 | Inspected feature DOES NOT currently meet acceptable standards or a safety feature is required and NONE IS PROVIDED. |
| 1 | Inspected feature MEETS currently acceptable standards. |
| N | NOT APPLICABLE |

2. Superstructure, Substructure, Channel and Channel Protection, and Approach.

| *Code* | *Description* |
|---|---|
| *N* | NOT APPLICABLE |
| 9 | EXCELLENT CONDITION |
| 8 | VERY GOOD CONDITION-no problems noted. |
| 7 | GOOD CONDITION-some minor problems. |
| 6 | SATISFACTORY CONDITION-structural elements show some minor deterioration. |
| 5 | FAIR CONDITION-all primary structural elements are sound but may have minor section loss, cracking, spalling or scour. |
| 4 | POOR CONDITION-advanced section loss, deterioration, spalling or scour. |
| 3 | SERIOUS CONDITION-loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present. |
| 2 | CRITICAL CONDITION-advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support.<br>Unless closely monitored it may be necessary to close the bridge until corrective action is taken. |
| 1 | "IMMINENT" FAILURE CONDITION-major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service. |
| 0 | FAILED CONDITION-out of service-beyond corrective action. |

3. Supplemental for Channel and Channel Protection (Use in conjunction with part 2 above).

| *Code* | *Description* |
|---|---|
| N | NOT APPLICABLE bridge is not over a waterway. |
| 9 | There are no noticeable or noteworthy deficiencies which affect the condition of the channel. |
| 8 | Banks are protected or well vegetated. River control devices such as spur dikes and embankment protection are not required or are in a stable condition. |
| 7 | Bank protection is in need of minor repairs. River control devices and embankment protection have little minor damage. Banks and/or channel have minor amounts of drift. |
| 6 | Bank is beginning to slump. River control devices and embankment protection have widespread minor damage. There is minor stream bed movement evident. Debris is restricting the waterway slightly. |
| 5 | Bank protection is being eroded. River control devices or embankment have major damage. Trees and brush restrict the channel. |

| *Code* | *Description* |
|---|---|
| 4 | Bank and embankment protection is severely undermined. River control devices have severe damage. Large deposits of debris are in the waterways. |
| 3 | Bank protection has failed. River control devices have been destroyed. Stream bed aggradation, degradation, or lateral movement has changed the waterway to now threaten the bridge or approach roadway. |
| 2 | The waterway has changed to the extent the bridge is near a state of collapse. |
| 1 | Bridge is closed because of channel failure. Corrective action may put it back in light service. |
| 0 | Bridge is closed because of channel failure. Replacement is necessary. |

4. Supplemental for Approach Roadway Alignment (Use in conjunction with part 2 above):

| *Code* | *Description* |
|---|---|
| 8 | Speed reduction is NOT required. |
| 6 | A VERY MINOR speed reduction is required. |
| 3 | A SUBSTANTIAL speed reduction is required. |

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