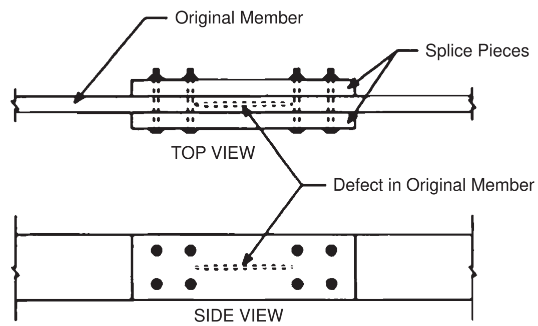


FIGURE 3-57. Splicing Augmentation

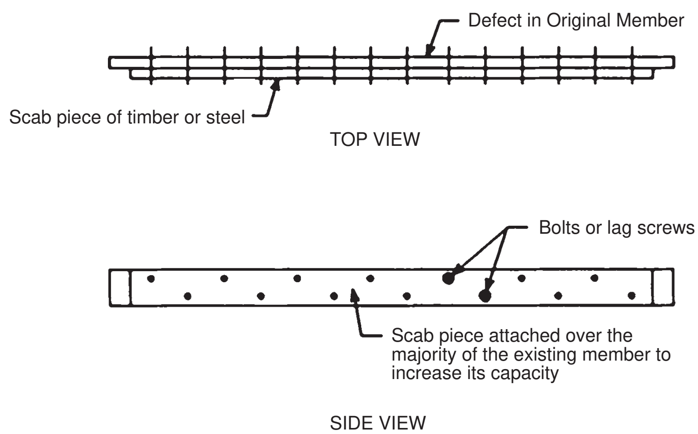


FIGURE 3-58. Scabbing Augmentation

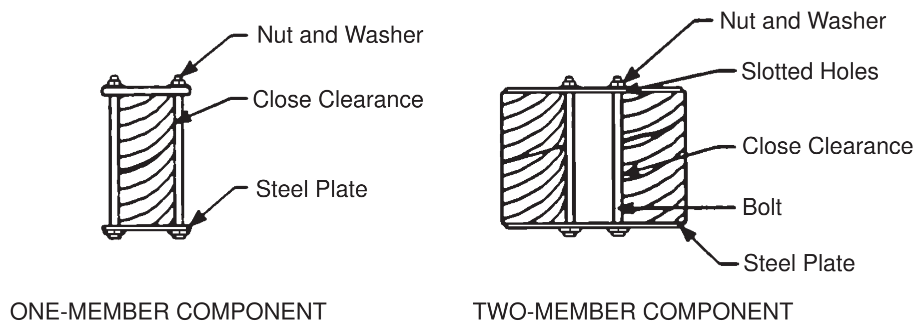


FIGURE 3-59. Clamping

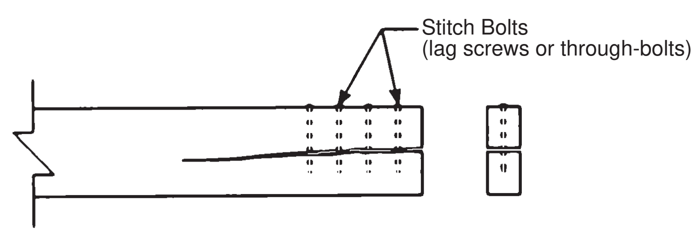


FIGURE 3-60. Stitching

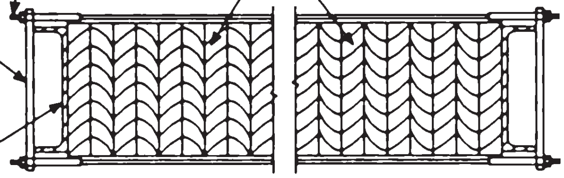


FIGURE 3-61. External Stress-Laminated Deck

areas (e.g., around the planking spikes), but in many cases this repair will be as costly in time and effort as replacing the stringer. Furthermore, not replacing the stringer leaves a weakened structural member with a short service life until it must be replaced.

In many cases, it is easier to replace a damaged timber beam if the deck is removed, but if the deck is heavily spiked to all of the beams and only one beam is damaged, this may not be practical. To deal with the situation where it is not practical to remove the deck, a new beam is installed next to the existing damaged beam (or perhaps a new beam on each side of the old beam). The new beam can be trimmed at an angle on one end, providing space to insert enough of the trimmed end between the pier cap and the underside of the bridge deck so that the new beam can be rotated up against the deck and slid into place over the other pier cap. (If a new beam is placed on each side of the existing beam, it may be better to trim the opposite ends of each new beam.) After the new beam is in position over both pier caps, it should be jacked tightly up against the deck and shimmed with hardwood or metal shims between the beam and pier cap. (The material trimmed off the beam end can be used to make shims.) The deck is then spiked to the new beam (or beams).

3.1.4.4 Truss Repair

Truss bridges are usually made of steel, although some old trusses constructed of wrought iron still exist. Generally, repair consists of replacing a damaged member or of strengthening a weakened member by adding steel plates to it. Welding should be avoided if at all possible in repairing older trusses since the steel typically has a high carbon content. A professionally qualified structural engineer should make an assessment of the appropriate repair process to be applied to a truss bridge, especially since the methods used to support the structure may be much different for repair of a member carrying compression loads than for one carrying a tensile force.

Maintenance and Repair of Steel Trusses. All steel trusses are susceptible to damage from rust and corrosion. In most truss designs, the main load-carrying members cannot suffer a substantial loss of cross-sectional area without beginning to lose capacity to withstand design stress levels. Through trusses and pony trusses are generally narrow and especially susceptible to damage from vehicle collisions because the exposed truss members are close to the traveled roadway. Portal and sway bracing of through trusses is also susceptible to collision damage from over-height loads. The condition of connecting pins is critical in maintaining the structural integrity of a truss with pin-connected eyebars. Since all loads pass through the pin, failure of the pin can cause a complete structural failure of the entire span. A regular, thorough cleaning and spot-painting program is necessary to prevent rust and corrosion damage in all types of truss bridges. Cleaning of pin-connected joints is a critical maintenance activity in pin-connected trusses to ensure that the joints are free to move as the loads are transferred across the bridge. Repair procedures commonly applied to truss bridges to correct deficiencies are as follows:

- If truss members have been damaged by rust or corrosion and a structural engineering analysis indicates the member is overstressed for its reduced cross section, plates are typically added to the member to compensate for the lost section area.

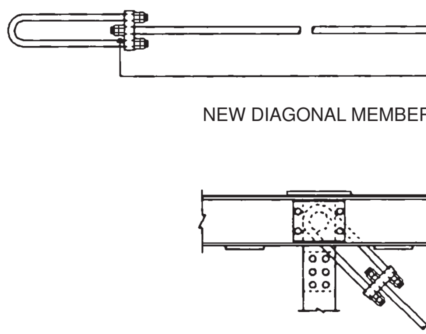
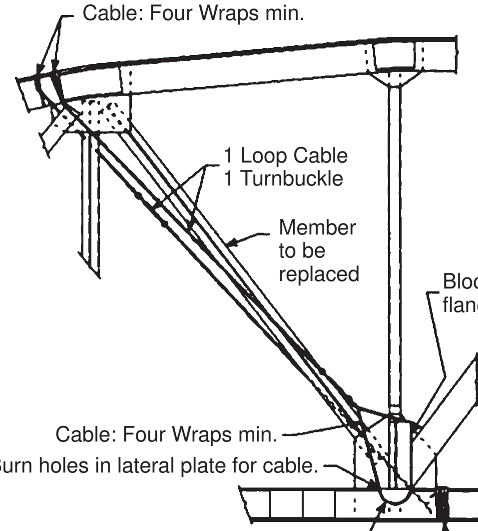


FIGURE 3-62. Truss Diagonal Replacement for Pinned End Connections



Note: Cable for wraps is same size as main cable.

FIGURE 3-63. Truss Diagonal Replacement for Riveted or Bolted Connections

- Truss members that have impact damage from collisions may be temporarily repaired using a strut to reinforce damaged members carrying compression loads and using cables with turnbuckles to reinforce damaged members carrying tension loads. If a collision impact has fractured a member, the member usually must be partially replaced and perhaps the entire truss member will have to be replaced.

- A fractured eye-bar of a pin-connected truss can also be temporarily repaired with a cable to accept part of the stress. However, permanent repair will require that the fractured member be replaced.

Damage from collision impacts to truss bridges can often be reduced by upgrading the bridge railing to provide structural protection to the truss. Sometimes, it is possible for bridge design engineers to develop a revised network of overhead lateral bracing to increase overhead clearance if a truss is frequently being hit by over-height loads. Some agencies have also found it helpful to install overhead devices that warn truck drivers that their load will not clear the truss overhead bracing.

Repairing Tension Members. Diagonal tension members may be damaged by corrosion, overload, or impacts from oversized vehicles. A general procedure to guide the repair of tension members should contain the following activities:

1. Design and acquire a replacement member that meets the load capacity requirements, including any additional load created by the repair process.
2. If the bridge is open to traffic, restrict traffic to one lane on the opposite side of the bridge.
3. Cut and install wood blocking.
4. Install a cable having the capacity to carry the full dead load in the diagonal plus any live load distributed from the restricted traffic flow.
5. Tighten the cable system.
6. Remove and replace the damaged member. If the old and the new member consist of more than one section, the sections should be removed and replaced individually, using high-strength bolts and keeping the load as symmetrical as possible.
7. Install batten plates or lacing bars at the required intervals along the diagonal and tighten all high-strength bolts in the new member.
8. Remove the cable support and other temporary components, and restore the bridge to normal traffic flow conditions.

A vertical tension member can be repaired using the same general process with cable supports. Damaged diagonal tension members consisting of two eye-bars can be replaced by using rods with U-bolt end connections. With no traffic on the structure, one of the eye-bars can usually be replaced at a time.

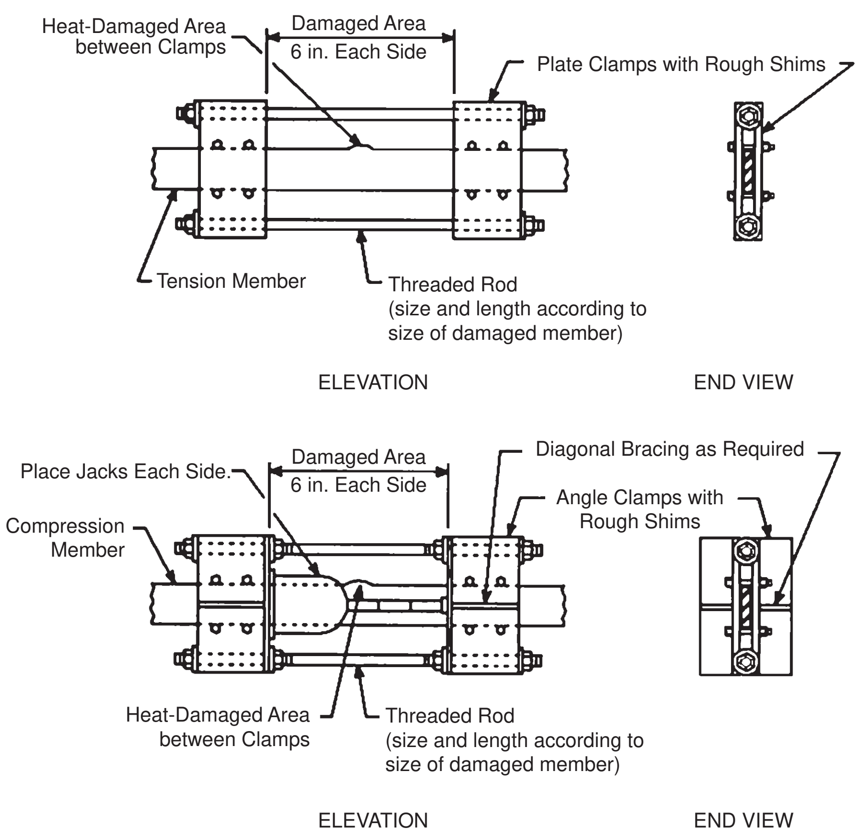


FIGURE 3-64. Yoke for Restoring Tension and Compression Members by Heat-Strengthening Method

Replacing Compression Members. The difference between replacing a compression member and replacing a tension member is that a heavier, more expensive temporary support system is needed for the compression member.

- The temporary support system must be capable of supporting the compression load while the member is removed and replaced. Therefore, each member that makes up the temporary support system will consist of a large, "column-like" section.
- To provide room for removing the old compression member, the temporary support must be framed around the old member. It is not mandatory that the temporary support be more than one column; however, since the temporary support is offset, it must be able to resist the unbalanced load that is created when the old member is removed.
- As the temporary support is installed, the load on the damaged member must be relieved by jacking. The temporary support is designed to support each (and all) jack(s).

Repairing Damaged Truss Members. If the damage is localized, such as a transverse crack in one of two channels that make up the bottom chord of a truss, a professionally qualified structural engineer can design a splice as a repair solution. The basic repair steps are as follows:

1. Bolt a side splice plate to the damaged member. Remove any rivet heads that would interfere with the splice plate if the repair is near a connection. The plate should be centered over the damage and sized by a professionally qualified structural engineer.
2. If necessary, remove the old tie plates (or lacing bars) from the two channels in the area of the crack, facilitating placement of the bottom tie plate. Some temporary lateral bracing may be required before completing the repair.
3. Bolt the bottom tie plate to the member.

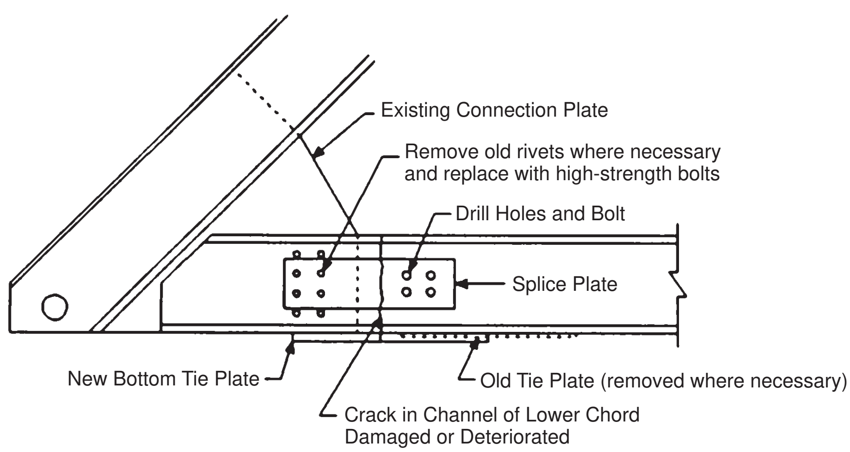


FIGURE 3-65. Typical Truss Repair Where Complete Removal Is Not Necessary

Increasing Vertical Clearance by Modifying the Portal Bracing. On many older through trusses, vertical clearance is restricted as allowed by modern transportation regulations. The clearance is controlled by the portal brace connected to the top chord, or the end post at the end of the span, or both. The primary purpose of the portal brace is to support the truss against lateral wind loads; however, it may have been designed also to provide support against buckling in the end post. The portal bracing can be modified to increase vertical clearance by replacing it with a shorter depth truss pattern bracing that has an equivalent or greater strength to resist expected wind loads. Thus, it is important that changes to the portal bracing be designed by a professionally qualified structural

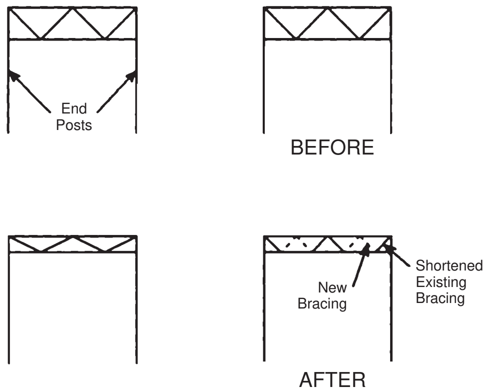


FIGURE 3-66. Examples of Portal Modifications

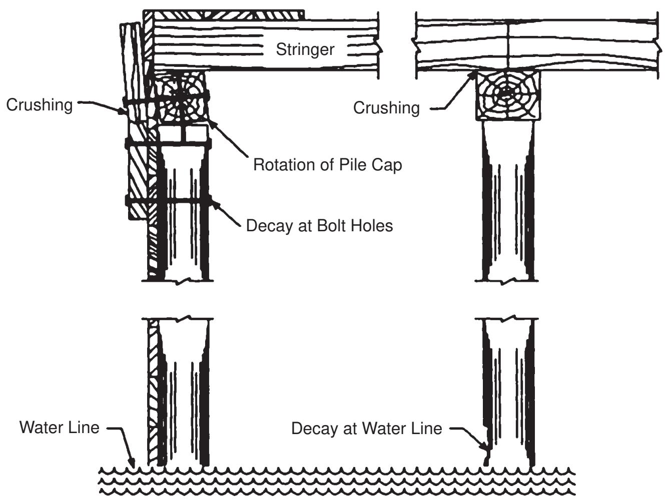


FIGURE 3-67. Defects Common to Timber Substructure

engineer, and the load-bearing capacity of the end post needs to be checked since the unsupported length may be changed.

Heat Straightening Damaged Truss Members. The Minnesota DOT has successfully repaired damaged truss members using heat-straightening methods. The load is removed from the member to prevent stretching or buckling of the heated steel. Yokes are installed to accomplish this. The yokes are designed to act as either compression or tension members. Generally, the steps conducted to repair a bridge are as follows:

1. Exclude vehicle traffic from the damaged side of the bridge.
2. Identify whether the damaged member carries tension or compression and obtain or fabricate the necessary yoke.
3. Tighten the clamps of the yoke around the damaged portion of the member.
4. On tension members, progressively tighten the threaded rods to remove tension stress in the damaged member. On compression members, simultaneously apply jacking forces parallel to the member until the compression stress is relieved in the damaged member.

5. Using an oxyacetylene torch, apply heat to the member until a dull red color is reached. Do not exceed 650°C (1200°F). First apply the heat at the bottom point of a V pattern; then slowly work back and forth and progressively outwards in the V.
6. Hammer-peen the elongated side to the bent member, eliminating high residual stresses.
7. As the heated area cools, shrinking occurs that tends to return the bent portion to its original shape.
8. If the first attempt at straightening is inadequate, this process can be repeated after the steel cools.
9. Remove yoke and paint exposed steel.

3.1.5 Substructure

Substructure caps of both the abutments and the piers provide seats or bases upon which bearing systems rest that directly support the superstructure. Many bridges have open joints located over the abutments and piers. Some bridges have drainage troughs located below the open joints to intercept the runoff and debris that falls through the deck expansion joints. These troughs discharge the debris beyond the substructure units into the watercourse or onto the ground below.

3.1.5.1 Problems Associated with Substructure Caps

The presence of debris on the caps results in corrosion of the bearing systems since the debris tends to hold water (and associated deicing chemicals in freeze-thaw climates) for extended periods of time. The penetration of deicing chemicals into concrete can corrode reinforcing steel, which in turn expands and breaks out (spalls) the covering concrete.

When the bearing system is frozen by corrosion, additional stress is introduced into the substructure cap that can cause spalling or damage to the bearing system. In addition, if the superstructure or deck joints are not kept clear of debris, the joint may not close as the deck expands, and the deck can be prevented from expanding as it was designed to do. Deck expansion is generally in the range of 50 mm per 100 m of length (approximately $^5/_8$ in. per 100 ft). If no other expansion joint can compensate for the jammed joint, the expansion force will be transmitted to the bearing system. Overloading the bearing system can result in fracture of the substructure cap and loss of bearing for the beam ends.

3.1.5.2 Maintenance

Maintenance of the substructure should include routine cleaning of the substructure cap. Using a high-pressure pump with sufficient hose length to flush out the substructure cap from every angle is an effective method of cleaning. The superstructure expansion joint troughs and drainage system downspouts should be cleaned at the same time. This procedure should be scheduled in the spring as soon as the winter deicing program is over in freeze-thaw climates and at regular intervals in warm climates, depending upon local conditions. Flushing the bridge deck should also be included as a part of this maintenance. The flushing and cleaning process proceeds from the top down. If water supply is limited, the substructure caps can be cleaned first and then the downspouts can be flushed. Rainstorms will flush the deck and the drains, but do not contribute to cleaning of the substructure caps.

3.1.5.3 Preventive Maintenance

A program of effective preventive maintenance generally includes the following items:

- If they can be accommodated in the structure, drain troughs can be installed in deck expansion joints to protect caps for bridges that do not already have such troughs.

- Surface protection of the concrete in the substructure caps should be applied, using one of the commonly available surface treatments.

Sealants. The concrete surface can be impregnated to reduce surface porosity and stabilize the surface layer of concrete. Typical sealants include silane, silicate, siloxane, and high-molecular-weight methacrylate (HMWM).

Coatings. Coatings that will adhere to the concrete surface, seal it, bridge small cracks, and provide some resistance to deicing chemicals include epoxy resins, hard urethanes, and methacrylate.

Membranes. Membranes that can bridge cracks and provide good protection of the concrete surface from deicing chemicals include elastomeric urethane, vinylester, and polyester.

Some agencies apply the protective coating to the beam-bearing systems as well as to the substructure caps. This procedure can only be effective if the protective coating is compatible with the paint system used on the bearings. When coating concrete caps, extend the protective film on the abutments a minimum of approximately 0.3 m (1 ft) below the bearing seat. On piers, the extent of the coating may depend on the appearance that needs to be maintained for aesthetic considerations.

3.1.5.4 Repair Process

Problems often found in concrete bridge seats include deterioration of concrete and corrosion of the reinforcing steel. Such problems are caused by moisture and contaminants falling through leaking deck joints. A horizontal crack along the face of the pier cap, 75 to 100 mm (approximately 3 to 4 in.) from the top, normally indicates that the top mat of reinforcing steel has expanded because of corrosion and has forced up the concrete (i.e., delaminated it).

When a superstructure moves beyond the space that is provided for it in the bearing assemblies, pressure is created on the anchor bolts. This can be caused by an inadequate design, improper placement of the bearing assemblies, or corrosion of the sliding surfaces, which produces friction. Occasionally, lateral forces from large chunks of debris hitting a bridge during flood flows or high water levels, or an over-height vehicle hitting a beam can also create large forces on the anchor bolts. The pressure from the anchor bolts is then transmitted to the substructure cap, which can damage the bridge seats or cause cracks in other parts of the substructure (such as the columns).

No bearing device was provided on some older concrete bridges except for a thin fabric or paper bond breaker. Friction created by the beam or bearing device sliding directly on the bridge seat can cause the edge of the seat to shear if insufficient reinforcing steel exists in this area.

Planning for maintenance repair of the substructure should consider the following:

- Identify the extent of the damage by sounding the concrete and marking the areas of unsound concrete.
- Make provisions to correct the cause of the damage.
- Plan to remove vehicular traffic from the bridge during jacking operations.
- Determine the size, number, and location of jacks that will be required.
- Ensure that jacking will not damage joints, bearing assemblies, or the area supporting jacks.
- Define the needed resources, which generally include jacking equipment, form carpentry, concrete sawing or chipping equipment, and any necessary staging.

The substructure cap can be repaired or a new cap cast to offset any settlement that may have occurred at the substructure. Reconstruction of a bridge cap requires raising the superstructure to provide work space as well as to take the load off the bridge cap.

1. Construct a temporary bent for supporting the jacks and blocking, if jacking from abutment of pier elements cannot be done.
2. Remove vehicular traffic from the bridge while jacking the superstructure.
3. Lift the jacks in unison to prevent a concentration of stress in one area and possible damage to the superstructure.
4. If the bridge will carry vehicular traffic during repairs, restrict the traffic away from the repair area as much as possible.
5. Saw cut around the concrete to be removed and avoid cutting any reinforcing steel.
6. Remove deteriorated concrete to the horizontal and vertical planes, using pneumatic breakers.
7. Add new reinforcing steel where it is required.
8. Apply bonding material to the prepared concrete surface that must interface with the new concrete to be placed.
9. Build forms for the new concrete as required and place the new concrete.
10. Service, repair, or replace the bearings, as needed.
11. After the new concrete has cured and reached its required strength, remove forms, blocking, jacks, and temporary supports.

Recent field trials have successfully applied carbon fiber composite material to repair pier caps *(11)*.

3.1.5.5 Repairing Substructures Above Water

Repairs to the substructure are usually done with basic materials and processes. Repairs underwater require special considerations, as do pile and pile bent repairs. Substructure problems include deterioration (especially at the water line), cracking (usually related to settlement), impact damage (associated with traffic under the bridge), and shear damage (associated with movement or approach pavement pressure). Since most substructure units are concrete, repairs are often concrete-related processes. If the concrete substructure is exposed to saltwater, either from the deck or from below, problems such as those found in concrete bridge decks, including corrosion of reinforcing steel and concrete spalling, are likely to have occurred. Timber substructures can be damaged by decay and vermin attack. Substructure repairs are generally very costly because of the extensive temporary supports needed to carry the superstructure. Thus, preventive maintenance is often a very cost-effective approach to limiting these expensive repairs, especially a program that removes debris and pressure-washes seats, caps, and other substructure surfaces exposed to salt.

Repairing Broken or Deteriorated Wing Walls. Portions of an otherwise sound wing wall may be broken off by frost heave, ice that forms in voids created by fill settlement adjacent to the wall, ice in cracks, voids in the concrete, or insufficient air entrainment voids. Deterioration may result from deicing and from salt-rich snow and ice being plowed onto the wing walls where it piles up. Weak aggregate in the original concrete mix can also contribute to wing wall deterioration. Losing portions of a wing wall can result in erosion of the fill and further damage to the bridge approach. The cause of the wing wall failure must be determined so it can be corrected as part of the wing wall repair process. Concrete forming should be preplanned and the forming materials cut to size in advance, if possible. Any excavation required to gain sufficient working access and to facilitate removal of defective concrete can be accomplished in advance of the wing wall repair. Materials and equipment typically needed to make this type of repair vary widely but often include excavating equipment such as a backhoe, an air drill, tie screws or equivalent bolts, wood spacers (walers, etc.), reinforcing bars, granular backfill material, hand tools, concrete removal equipment, anchor bolts and anchors, plywood forming, portland cement concrete, epoxy bonding agent, nonshrink grout, and miscellaneous hardware. Everything needs to be readily available to limit the exposure of maintenance personnel to traffic and to expedite the repair operation.

1. Excavate as required to be able to set the dowels and the concrete forms.
2. Remove all fractured or deteriorated concrete to sound concrete by chipping and then blast-clean to remove all loosened surface material.
3. Drill and set form anchor bolts and dowels. Typically, dowels 13 mm in diameter (No. 4 bars) are placed a minimum of 225 mm (9 in.) into sound concrete and set with nonshrink grout, 150 mm (18 in.) center-to-center, both front and back.
4. Crosslace the 13-mm (No. 4) reinforcing steel bars and set the concrete forms.
5. Just before placing the concrete, apply an epoxy bonding agent to all existing concrete that will contact the new concrete.
6. Before backfilling with granular material, cure the new concrete a minimum of 7 days or until the concrete has developed sufficient strength to resist the lateral pressures of the backfill.

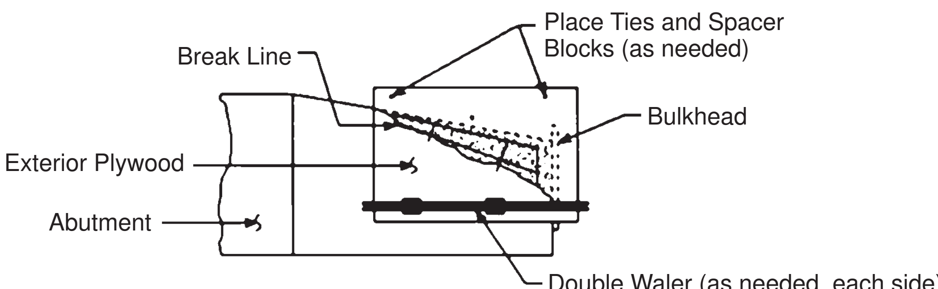


FIGURE 3-68. Reconstruction of Wing Wall

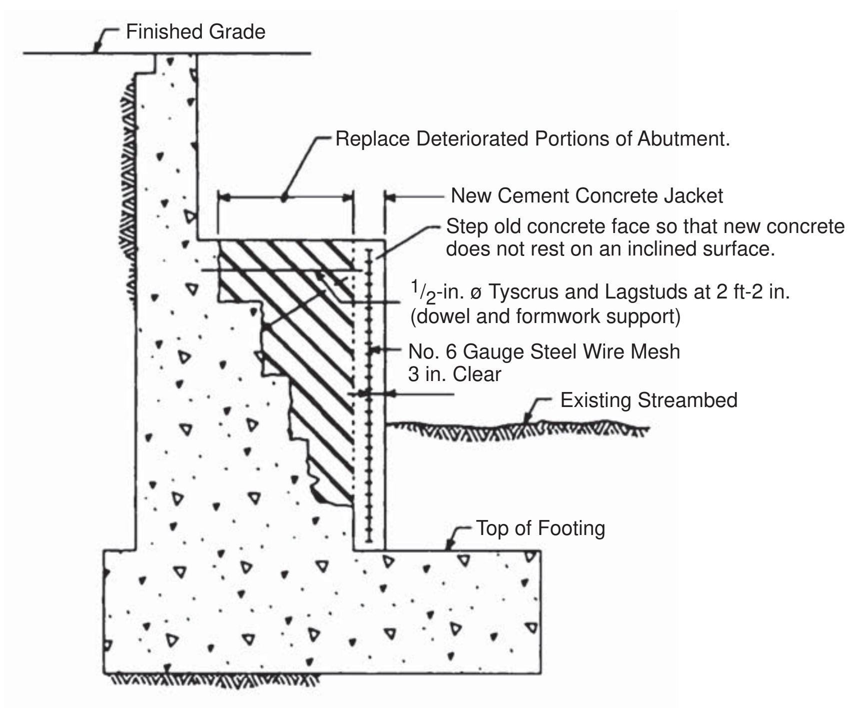


FIGURE 3-69. Repair of Abutment Face