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Chapter 11 - Superstructure

The superstructure consists of the structural framing system supporting the deck, which can include beams, diaphragms, trusses, floorbeam and stringer arrangements, to name a few. Although the deck is designed to carry vehicular loading it also serves as a protective cover for the framing, bearings and substructure. The deck joints are also critical in protecting the bearings, framing members, and substructure from exposure to the corrosive salt-laden runoff of the roadway.

11.1 Preventive and Basic Maintenance of Concrete Superstructures

There are many different types of concrete superstructures, including:

- Concrete slabs (solid and voided slabs)
- Concrete frames, concrete arches
- Concrete Tee beams or T-beams (Bulb Tee, Double Tee, Quad Tee and Rib Tee)
- Prestressed concrete I-girders
- Prestressed concrete slabs and box beams/box girders (single, spread or multiple/adjacent)

Preventing concrete deterioration is much easier and more economical than repairing deteriorated concrete. This prevention begins in the design of the structure with the selection of the proper materials, detailing, mixture proportions, concrete placement, and curing procedures. Even a well-designed concrete superstructure will generally require follow-up maintenance action.

Below are some examples of design and construction considerations that improve or affect the durability of superstructures:

- Precast prestressed structures – manufactured assembly line style in a large yard, the fast pace of girder production ignores some basic concepts of concrete preventive maintenance such as concrete cover. The ends of prestressed concrete girders usually have exposed high strength steel strands which can quickly corrode. Some bridge owners require the strands to be exposed, cut and covered with mortar. Many do not require any modification. Figure 11.1 shows a precast beam in place seated on an abutment with potentially inadequate cover for strands. Although the figure shows exposed strands, this may not necessarily be a problem. For example, if the end of the girder is encased in concrete, as with an integral abutment, the strand ends are only exposed for a short period of time until the abutment is poured.

Figure 11.1 Exposed Strands on End of Precast Prestressed Concrete Girder

- Precoating of girders – Applying surface protection to critical areas of the concrete girder such as its ends can extend the service life of the girder. Researchers in Wisconsin have found the most effective way of preventing beam end corrosion was to apply a polymer resin coating to the beam ends before installing them in the field.
- Drainage – design of drainage that will prohibit water from leaking onto the concrete; for example, extending drain pipes 6 inches beyond the lower face of the superstructure.
- Precast box girders – This particular structure type can be problematic from a maintenance standpoint. Construction of precast prestressed concrete placed directly adjacent to one another can be troublesome to inspect and maintain. Maintenance issues for this type of superstructure include:
    - Clogged drains leading to water in the voided cells of the box
    - Shear key failure between adjacent box beams leading to overload and reflective cracking into the bridge deck
    - Exposed strands on beam ends corroding quickly
    - See Section 11.4.7 for additional discussion on precast box girders

As an example of how details and specifications play such an important role in future bridge maintenance, there are many precast box girders that have been in service for 25 years that have not experienced any of the problems noted above. Poured in place concrete decks over the box girders have eliminated the shear key failure issues, and recent construction specifications have called for exposed strands to be coated and covered.

The primary types of maintenance for concrete are:

- Cleaning (Section 11.1.1)
- Surface protection (Section 11.1.3)
- Joint restoration (Chapter 8)
- Minor concrete repair (Section 11.1.4)

The approach to preventive maintenance for concrete superstructures varies from owner to owner. There are owners that clean and wash their bridges regularly, but many do not. Some bridge owners mandate a surface protection be applied to the concrete during initial construction, some never require it. However, it is generally recognized that a clean and protected concrete surface is beneficial.

What To Look For

In providing maintenance to concrete superstructures, it is always important to look out for a superstructure that may be in distress. This could include:

- Overheight vehicular impact damage
- Large cracks greater than 1/8 inch in reinforced concrete
- Spalls that expose reinforcement

11.1.1 Cleaning

Cleaning of concrete superstructures is extremely important. Regular cleaning of the superstructure members is necessary to remove accumulation of sand, debris, bird droppings, and other harmful material by flushing with high-pressure water jet or compressed air, sweeping, or shoveling to remove build up. This is particularly critical in areas where there are likely to be chlorides in the debris or on surfaces, such as areas where salt is used for snow and ice control, and marine environments.

In addition to cleaning for concrete surfaces, ancillary elements such as drains should be cleared to allow proper drainage off the structure. An example of preventive maintenance as applied to drainage is the extension of vertical drain pipes to 6 inches beyond the lower flange of the concrete girder (See Chapter 10).

11.1.1.1 Debris Removal

Traffic, pedestrians, animals, and/or flooding cause superstructure debris. All debris should be removed for safety reasons. Additionally, debris should be removed to prevent deterioration in areas where debris accumulates and can trap moisture such as on flanges and diaphragms. This debris could be considered hazardous and prior to removal and disposal local environmental protection requirements should be checked.

11.1.1.2 Power Washing

Power washing the concrete superstructure removes the salts that have accumulated and/or adhered to the superstructure. Areas include sides of beams and diaphragms exposed to spray or where water has come off the deck, beam ends and seats under deck joints, and at deck joints or drains that leak or allow water through. Other areas could include sides of beams adjacent to deck drains.

11.1.2 Bird Control

If bird nesting or congregation is apparent, these areas should be cleaned and screens, spikes or other deterrents installed, as shown in Figure 11.2. Here a simple rubber cylinder was installed to fill in the gap between bridge bearings where a bird can build a nest. There are so many forms of bird habitat controls available, they could not be covered in this manual. Past experience or internet searches are suggested to obtain the right solution for a particular bridge. Caution should be exercised as there may be restrictions due to federal protection of birds or other species such as bats.

Figure 11.2 Evidence of Bird Nesting (left) and a Rubber Cylinder Deterrent (right)

11.1.3 Concrete Superstructure Protection

Concrete superstructures are shielded from much of the traffic and weather by the bridge deck. The areas of concrete superstructures that can require protection are areas below deck joints, around deck drainage components, and on exterior girders. The noted superstructure concrete areas are exposed to spray or water flowing from the bridge deck and are thus susceptible to chloride exposure and the potential for freeze thaw damage.

The most common treatment to protect the concrete from water and chlorides is to apply spray on waterproofing products. Waterproofing products fall into two general classes: pore blockers and hydrophobic (water repelling) products. Pore blockers typically used are epoxies and silanes or siloxanes. Epoxy materials are also popular to treat beam ends under joints.

While the entire superstructure can be coated with protection, the application is often directed to critical areas such as beam ends.

Suggested Procedure

Spray-Application of Concrete Protection

1. Clean the area to be treated with high pressure water or light sand blasting.
2. Use compressed air to remove all loose dust or debris when dry.
3. Apply the waterproofing products according to the manufacturer recommended method (typically spray applied using low pressure sprayers). Spray evenly on dry concrete starting at the lowest point and working up.

An effective method of preventing beam end corrosion is to apply a polymer resin coating to beam ends before installing them in the field. Epoxy coating is the most commonly used polymer. An alternative treatment is to apply a penetrating sealer to the concrete end beams. Use of a Fiber Reinforced Polymer (FRP) wrap can be about equally effective, but is more costly and difficult to install than the polymer coating and is usually only used as a repair measure.

11.1.4 Spall and Crack Repair

Preventive and basic maintenance of concrete superstructures focuses on preventing the deterioration of reinforcing steel. Minor cracking, scaling and spalling can exacerbate the corrosion of rebar by allowing corrosive water and salt to infiltrate the concrete. Cracks or spalls large enough to affect the structural design or make the bridge unsafe for vehicular or pedestrian traffic will be covered in Section 11.4 Maintenance and Repair of Concrete Superstructures.

Minor cracking can often be repaired with sealants or by other penetrating materials such as silane, methacrylate, or epoxy. Flexible joint sealants, epoxies and cement grouts are the most common maintenance for routed cracks, which is a crack that is intentionally widened near the surface, while epoxy injection is also an option for cracks as narrow as 0.002 inches, as shown in Figure 11.3 through Figure 11.4.

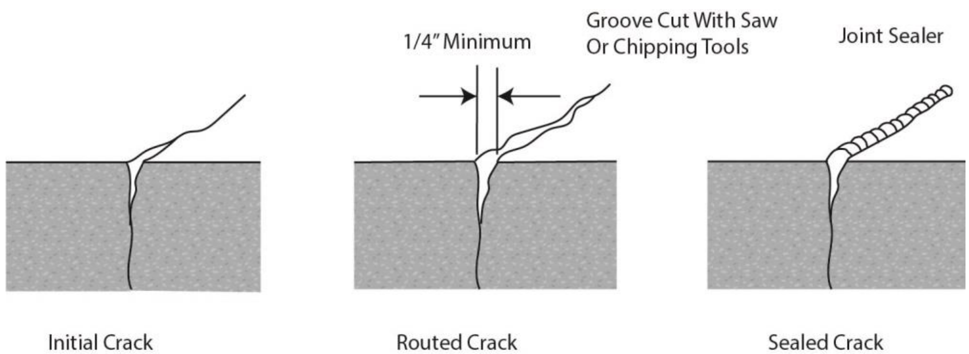


Figure 11.3 Conventional Procedure for Sealing Cracks

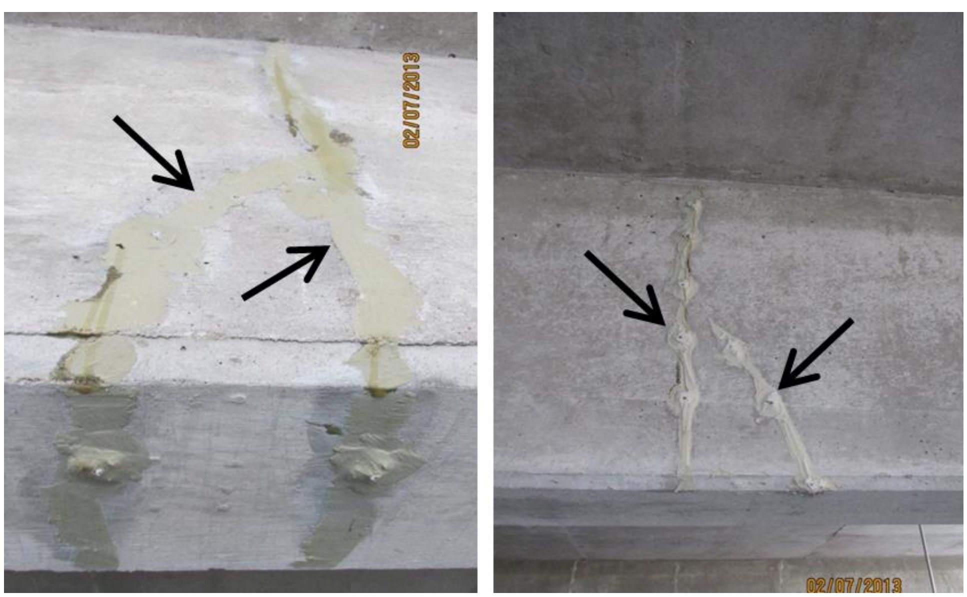


Figure 11.4 Epoxy Injected Cracks on a Superstructure

To prevent minor scaling and spalling from growing into a major repair, it is best to remove unsound concrete as soon as possible and replace with a concrete type material that will protect the steel reinforcement while being structurally adequate. Options may include a simple mortar patch for small areas to use of shotcrete for larger areas. Deeper spalls and repairs requiring formwork and replacement concrete are discussed later in Section 11.4 Maintenance and Repair of Concrete Superstructures.

In summary, preventive maintenance of concrete superstructures includes:

1. Keeping the concrete surfaces free of salt, dirt and debris by regular cleaning
2. Control and prevention of bird nesting and congregation which leads to deposits of corrosive waste
3. Inspecting for and repair of scaling, minor spalls, delaminations and cracks as soon as possible
4. Sealing the concrete to prevent chloride intrusion

11.2 Preventive and Basic Maintenance of Steel Superstructures

Preventive maintenance of steel superstructures consists mainly of measures to clean to steel and 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.

Common protective coatings for steel superstructures are weathering steel, galvanizing, metalizing, and paint. Weathering steel is a type of steel that forms its own protective coating and theoretically does not need painting. However, there have been cases of poor performance of bridges constructed with this type of steel. Therefore, members constructed from weathering steel should be monitored for excessive corrosion and be painted if necessary. Typical painting requirements are based on whether the steel is new or is to be repainted.

What To Look For

When performing maintenance on steel superstructures it is always good to see if anything does not look right. This includes:

- Impact damage to steel fascia girders. Generally, the girder being twisted and bent from impact
- Severe corrosion and section loss
- Bent cross frame members indicating movement and buckling

11.2.1 Cleaning

Similar to concrete superstructures, the cleaning of steel superstructures is extremely important. Regular cleaning of the superstructure members is necessary to remove accumulation of sand, debris, bird droppings, and other harmful material by flushing with high-pressure water jet or compressed air, sweeping, or shoveling to remove build up. This is particularly critical in areas where there are likely to be chlorides in the debris or on surfaces, such as areas where salt is used for snow and ice control, and marine environments.

Part of the cleaning process should be the clearing of any drains and downspouts that could clog and inadvertently flood steel components. A simple modification such as extending the superstructure drain pipe 6 inches below the bottom flange of the girder is considered a preventive maintenance task.

11.2.1.1 Debris Removal

Traffic, pedestrians, animals and/or flooding create superstructure debris. All debris should be removed for safety reasons and to prevent deterioration in areas where the debris accumulates and could trap moisture such as on flanges, diaphragms, gusset plates, etc. Steel bridges tend to collect debris more than concrete due to the complicated connection details and horizontal elements such as bottom flanges of girders.

11.2.1.2 Power Washing

Power washing the steel superstructure removes the salts and debris that have accumulated and/or adhered to the superstructure. Areas include sides of beams and diaphragms where water has come off the deck and at beam ends, under deck joints or drains that leak or allow water through. Other areas could include sides of beams adjacent to deck drains. A difference in the use of power washing for steel versus concrete superstructures is that every steel superstructure has some kind of protective coating that may be sensitive to very high pressures. Care should be exercised.

11.2.2 Bird Control

Bird waste can be quite corrosive, and the accumulation of nesting materials can prevent the proper draining of rainwater from the bridge, resulting in ponding which promotes corrosion. Steel bridges give birds plenty of areas to nest and stay out of the weather. In particular, steel bridges with wide flanges or gusset plates are attractive to birds, an example of which is shown in Figure 11.5. Trusses and towers also make particularly good nesting areas. Wash these areas and install bird screens or other deterrents routinely. As with concrete superstructures, maintenance workers should be aware of any environmental restrictions on federally protected wildlife.

Figure 11.5 Bird Nesting Signs on Steel Superstructure (left) and Behind Steel Girder (right)

11.2.3 Painting

Painting of steel superstructures should be performed on a regular basis with the repainting schedules based on the type of coating used, the environment, and the rate of coating deterioration. This routine maintenance prevents corrosion and section loss of the steel members. Painting operations require properly designed and approved containment systems. An example of a painting containment system is shown in Figure 11.6.

Figure 11.6 Painting Project with Approved Containment System

Less costly painting operations include:

- Spot Painting – Painting of localized areas on the steel superstructures that have lost their protective coating or areas of rust and corrosion. Once steel members begin to corrode, they begin to lose strength due to material loss. It is important that areas of spot rust be touched up routinely. The loose rust must always be removed before the touch up. Importantly, if the corrosion is due to exposure from a leaking drain or joint, maintenance or repair of the source defect must be coordinated with the spot painting. It is also critical to follow the coating manufacturer's recommendations for applying the coatings (temperature, humidity, and application method) to maximize the life of the coating.
- End of Beam Painting – Many agencies recommend painting / repainting superstructure steel within a distance of 1.5 times the depth of the girders from the bridge joints for extra protection. If aesthetics are a concern, the exposed areas of the fascia girders are painted for the entire girder length.

11.2.4 Weld Peening

Most modern structures use welding to connect steel plates. For the weld to be successful, the adjoining plates are brought up to a molten state as the weld material is added. Once everything cools down, there are built up stresses in the weld, as the weld material tends to shrink. This locked in tension stress is one of the reasons welds can crack. A unique idea is to apply a compressive force to the weld after the bridge is erected to counteract the tension. Imagine a hammer hitting the weld to compress it thereby relieving these built in stresses. That is the basic concept of peening.

Figure 11.7 shows a tool that uses oscillating impact pins at a very high frequency to compress the weld. This is usually performed by a trained technician. For this technology to work, the structure has to be in its final position, so if a bridge girder would need to be erected.

When to Call the Engineer

Call the Engineer before performing weld peening operations, as weld peening is not applicable in all situations.

Figure 11.7 Peening of Weld using Ultrasonic Impact Technology

The following references provide more information on peening:

- *NHI 134062 Bridge Rehabilitation and Design*, U.S. Department of Transportation, Federal Highway Administration
- http://digital.lib.lehigh.edu/fritz/pdf/417_2_77_.pdf
- http://www.fhwa.dot.gov/bridge/steel/pubs/hif13020/hif13020.pdf

In summary, preventive maintenance of steel superstructures includes:

- Keeping the steel surfaces free of salt, dirt and debris by regular cleaning
- Control and prevention of bird nesting and congregation which leads to deposits of corrosive waste
- Cleaning rust, painting and/or spot painting as needed
- Possible peening of welds
- Ensuring drainage downspouts extend at least 6 inches below the bottom flange of the girder

11.3 Preventive and Basic Maintenance of Timber Superstructures

There are many different types of timber superstructures, including:

- Log Beam
- Sawn Lumber
- Glulam Concrete slabs

What To Look For

When performing maintenance on timber superstructures, it is a good idea to look out for things that may cause structural distress to the bridge. This includes:

- Look out for large splits or cracks in the timber bridge elements
- Look out for broken or crushed timber
- Look out for excessive displacement of the timber girders indicating a possible overload
- Look out for excessive decay and insect damage

Preventing timber deterioration is much easier and more economical than repairing deteriorated timber. This prevention begins in the design of the structure with the selection of proper materials, preservatives, and other means to protect the timber from moisture.

11.3.1 Preventive Maintenance and Cleaning

Mechanical damage, insect attack and deterioration from decay are potential threats to even the most durable timber superstructures. Preventive and maintenance measures may be taken to keep structural members in good condition to reduce future problems. This would include regular cleaning.

11.3.2 Moisture Control

The most economical and simplest method of preventive maintenance is moisture control. Moisture contents within timber members of greater than 20 percent support fungal and insect growth. When exposure to wetness is reduced, fungal and insect growth is inhibited. A maintenance worker may utilize a moisture meter to measure moisture contents.

11.3.2.1 Identify Visible Area

Visibly high moisture content areas may be identified by locating the source of water and taking corrective action to eliminate the source.

11.3.2.2 Controlling Drainage on Timber Superstructures

Restricting water passage through the deck substantially reduces the potential of decay to structural members below. Bituminous roofing cement can be used to help seal all types of timber decks.

Lumber running planks used as a wearing surface are often subjected to water ponding. Installation of tubes through the deck can be used to drain water down and away from the deck and supporting members, as shown in Figure 11.8.

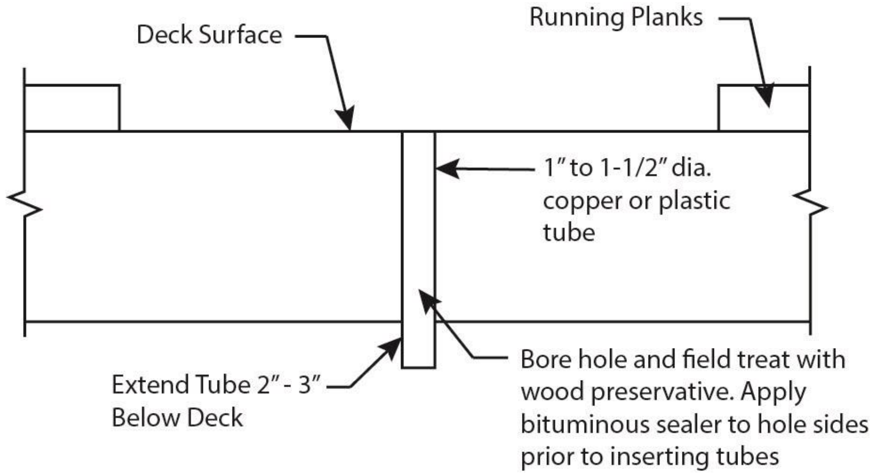


Figure 11.8 Installation of tubes through deck to drain water away from superstructure elements

11.3.3 In-Place Preservative Treatment

The application of a suitable preservative treatment will increase the longevity of a timber structure by reducing the effect of weathering, drying out, and surface rotting. In place preservative treatment is most effective when applied before decay begins and may be used to treat splits, checks, and delaminations. Additional surface treatment information, including surface treatment of new materials and pressure treatment, is included in Section 13.3.3 Preservation Treatments for Substructures.

11.3.3.1 Surface Treatments

Brushing or spraying the preservative in liquid form is the simplest and least expensive treatment. The wood surface should be thoroughly saturated in order for the preservative to be fully effective. It is preferable to apply preservative to dry wood. Wet wood absorbs less preservative than dry wood. If due to environmental issues, preservatives must be applied to wet wood, double the amount of preservative should be applied. Preservatives are available in oil based or water based solutions.

A commonly used oil base preservative for brush or spray applications is copper naphthenate. It is available as a concentrate or in ready–to-use liquid in drum or gallon containers. The use of bituminous or asphaltic pastes could be used as effective sealants.

Supplemental treatments for timber bridges have recently been boron based. Boron is a chemical element that has been effective against both decay fungi and insects and is not very toxic to humans and other mammals. Other advantages of borates are:

- Odorless
- Colorless
- Does not interfere with finishes
- Corrosion inhibitor
- Can be applied in multiple ways such as a powder, gel, paste or rod

Borate solutions are water-based and may be sprayed in checks or splits. However, borate preservatives may leach from the wood during precipitation. Borate solutions are sold as a concentrated liquid, powder, gel or rods.

Borate is effective when the wood is moist; at least 20 percent moisture content is needed to achieve diffusion, which is the movement of the chemical through the wood. At 40 percent moisture borate diffusion is very rapid. Thickened glycol-borate solutions are a syrupy type liquid that allows for a greater concentration of the chemical element than powder. The solution can be applied by spray or brush, or used to flood cut-ends or holes. Borate gels are available in tubes and can be applied by standard caulking guns. An advantage of the gel formulation is that it can be applied to voids, cracks, and any kind of holes. Borate gels are the most convenient but also most expensive. Lastly, a paste formulation of borate typically contains at least one component of borate that diffuses into the wood and at least one other that can provide long-term protection near the application. This method is popular for application to piles at the ground line.

Some preservative treatments besides borate are also available in semisolid greases or pastes which may be effectively applied to vertical surfaces. These commonly contain sodium fluoride, creosote, or pentachlorophenol.

In Figure 11.9, the stringer exhibits splitting and checking at the bottom. As long as the capacity of the beam is not compromised, it may be beneficial remove the deteriorated section, and to treat these stringers with a paste or semisolid grease to prevent further deterioration. It is recommended to apply these preservative treatments every 3 to 5 years.

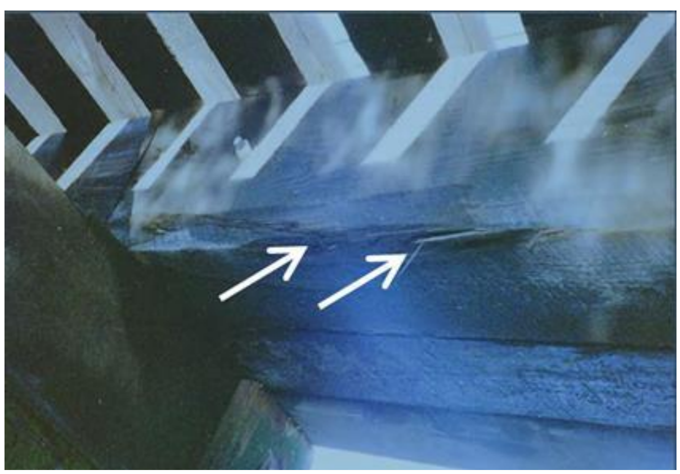


Figure 11.9 Splitting and Checking

11.3.3.2 Internal Treatments

Fumigants are gases used to internally treat large piles or timbers. Fumigant preservative chemicals are available in liquid or solid form that can be used to control internal decay from fungi and insects. The fumigants are placed in pre-bored holes. Over time, fumigant preservatives transform into gases which spread through the wood as much as 4 feet in horizontal members such as beams.

The pattern of bores may be determined by the condition of the wood. Fasteners, seasoning checks, badly decayed wood, and other openings to the atmosphere should be avoided.

Holes for application of fumigants in horizontal members such as beams should not be more than 4 feet apart. Additional information and recommended dosages for fumigants may be obtained from the chemical manufacturers.

Common Liquid fumigants used are Vapam (33-percent sodium N-methyldithiocarbamate), Vorlex (20-percent methylisothiocyanate, 80-percent chlorinated C3 hydrocarbons), and chloropicrin (trichloro-nitromethane). Liquid fumigants may be applied by using commercial equipment or may be applied from 1-pint polyethylene squeeze bottles. Liquid fumigants should not be stored in plastic bottles for long periods because the plastic can become brittle and crack. Leaks may sometimes occur during application of the fumigant, in which case the bore hole should be plugged and be moved to an alternate sound wood location.

Solid fumigants are typically composed of methylisothiocyanate (MIT), which is the active ingredient of Vorlex. Solid fumigants are inserted directly into the pre-bored holes. Holes should be placed on both sides of checks or splits and bored to within 1 ½ to 2 inches of the bottom of the member. The hole is plugged shortly after placing the chemicals with a treated-wood dowel driven tightly into the wood. This procedure is shown in Figure 11.10. A 10-year treatment cycle is recommended. When inspections indicate the presence of active decay, retreatment may be required sooner than the 10 year cycle. It is important to keep accurate records including the date and location of the application, the type of chemical, and the dose. A metal tag on the member noting treatment information may be placed. However, these tags should not be the sole means of recording treatment information, in case they are removed in between applications. The same holes may be used for retreatment, and the holes may be replugged.

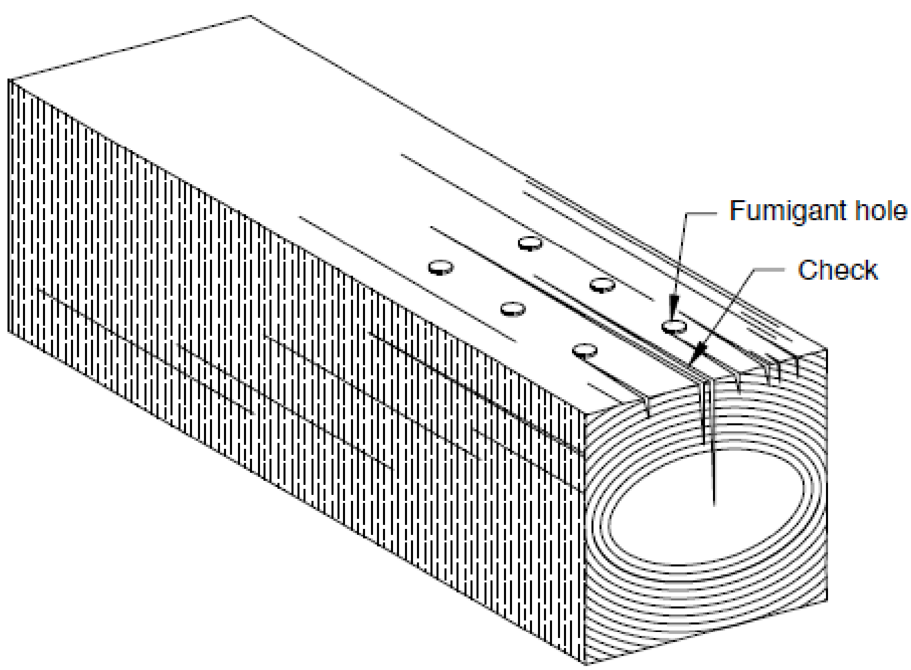


Figure 11.10 Solid Fumigant Inserted Directly into Pre-Bored Holes

For in-place application of fumigants, it is important to select an experienced contractor who fully understands their use and the required safeguards. The treatments are toxic to humans and must be used in accordance with State and Federal laws.

The treatments pose minimal environmental or health hazard when proper controls and precautions are applied. The environmental damage potential can be higher in some field locations due to the location, environment and distance from water sources. A gas mask with the appropriate filter available for emergency use should be available for fumigant applicators. When experiencing strong odor or eye irritation during fumigant application, all individuals should move upwind from the treating area and allow vapors to clear. When any form of in-place treatment is used, the procedures, precautions, and contingency for accidental spillage or injury should be well planned before beginning treatment. In-place treating by local maintenance crews is limited by the scope of the treatment required. For routine maintenance, the amount of treating required is normally minor, and local crews can be used when properly trained personnel are available. For larger projects involving many members or an entire structure, it is advisable to contract the project to specialists in the field. There are companies that have safely provided in-place treating services for many years.

Figure 11.11 shows examples of borate rods which range in size from 0.75 inch to 0.5 inch diameter.

Figure 11.11 Borate Rods

Borate rods contain compressed chemicals fused into a solid form produced by heating and molding. The advantage of the rod formulation is their ease of application and low risk of spillage. They can be applied to holes drilled upward from below a member. A disadvantage of the borate rod is that no water is applied, which is how the borate gets diffused into the timber.

11.3.4 Epoxy Repair

A major maintenance cost associated with timber construction is the repair of structural members near bolted joint connections which exhibit checking, cracking, and splitting. The use of pressure injected epoxy to repair damaged timber connections is an alternative which may be considered. Epoxy may also be manually applied as a gel or putty.

Suggested Procedure

Basic Epoxy Injection

1. Prepare member by cleaning
2. Determine areas for port injection and sealing
3. Inject the epoxy
4. Finish the surface, consider aesthetics

For manual application, port setting and joint sealing are not required.

Epoxy may be used as a grout to fill decay void, cavities, checks or splits to prevent water and other debris from entering. It forms a bond which aids in reducing further splitting and in preventing water and debris from entering the affected area. For surface repairs, voids may be filled with an epoxy gel. Liquid epoxy may be injected into a member exhibiting splits or insect damage.

When to Call the Engineer

An engineer should be consulted when removing large sections of the beam.

When the defect in the original member is the result of decay, the damaged wood must be removed to prevent further infection. If areas to be repaired show early signs of decay, in-place treatment may be adequate to help prevent decay, as long as the member strength is not compromised.

When removing decayed parts of members, it is recommended to remove visible decay plus an additional 2 feet of the adjacent wood in the grain direction. The moisture source should be identified and eliminated, if possible. When moist wood (greater that 20 percent moisture content) is found, the member should be dried before repairs are made. Although there are epoxies that will bond to moist wood, the presence of high moisture may provide conditions for continued fungal growth and deterioration. Surfaces must be thoroughly cleaned of all dirt and debris so that a good bond can be achieved between the wood and the epoxy.

To repair interior splits or voids in timber superstructures, epoxy can also be applied by pressure injection to reach these difficult areas. Ports must be installed and completely sealed before epoxy placement. The injection ports are holes bored into the timber member permitting epoxy injection into the member's interior. A port vent allows displaced air to escape as epoxy fills the void. The epoxy is distributed throughout the affected area when it exits the port vent. The minimum number of these ¼ inch to ¾ inch diameter ports is two. However, more may be required depending on the size of the repair area.

11.3.5 Stitching and Clamping

On timber-bridge trusses or other structures with a high number of small members, clamping and stitching steel are maintenance operations that may be utilized to prevent further development of cracks, splits, or delaminations. The objective is not to close the split or check, but rather to prevent it from further developing.

Clamping and stitching are similar in concept in that both compress the component in question. However, clamping uses bolts and two-plate assemblies whereas stitching uses bolts or lag screws through one side of the member. Stitching may also use a plate for added strength. Schematics of each are presented Figure 11.12. Although both methods have been used effectively, clamping with bolts and steel plates is generally preferable because the section of the member is not reduced.

Caution should be exercised installing metal components in high humidity environments where there is cyclical temperature change. Condensation may form on plate assemblies and bolts exacerbating moisture related problems in the wood.

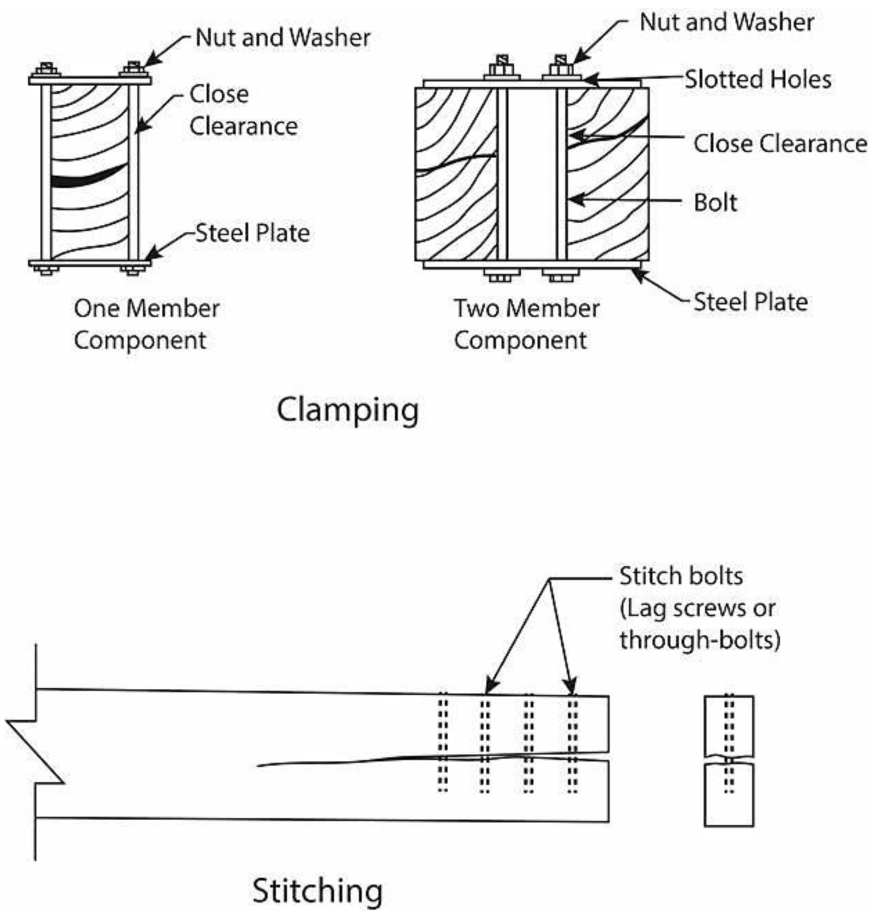


Figure 11.12 Typical Clamping (top) and Stitching (bottom) Details

11.4 Maintenance and Repair of Concrete Superstructures

What To Look For

- Spalls
- Cracking
- Efflorescence
- Leaking water
- Soft, unsound, or “punky” concrete
- Exposed reinforcing steel
- Section loss in reinforcing steel
- Exposed tensioning strands
- Damaged or broken tensioning strands

11.4.1 Introduction

The most common material for superstructure elements is concrete (reinforced or prestressed). Concrete is heavily used for bridge superstructures because it can be molded into almost any shape and has above average durability. Concrete superstructures may be precast in a plant or cast at the bridge site. Regardless of the type of concrete, the repair methods for the concrete material are similar.

All concrete superstructure elements use reinforcing steel to carry tensile and shear loads and limit cracking. Concrete superstructure elements typically use conventional reinforcing (rebar) or prestressing steel. The repair methods for conventional reinforcing and prestressed steel are different, which will be addressed in subsequent sections in this chapter. The main difference is that conventional reinforcing is passive and prestressed steel is active. A good analogy is a rubber band that is unstretched versus stretched.

This section presents common maintenance and repair techniques for concrete bridge superstructure elements.

11.4.2 Concrete Superstructure Patching

Concrete superstructure elements can be repaired using a number of techniques. The selection among the repair methods is dictated by the depth and extent of the concrete deterioration or damage. Concrete superstructure repairs are often required because of corrosion of reinforcing steel within the member, from traffic impact, or from freeze thaw damage. The repair of the concrete generally involves removing the deteriorated or damaged concrete and restoring the member with new concrete. Areas of concrete removal can be repaired in five different ways:

- Patching with trowel-applied or poured mortar
- Recasting with new concrete
- Prepacking dry aggregates and grouting
- Shotcrete
- Self-consolidating concrete

These methods of concrete removal are described in the following sections.

11.4.2.1 Patching

Patching small concrete spall areas with cementitious or resin mortars is the simplest of all concrete superstructure repair techniques. Concrete spalls between ½ and 2 inches deep can be repaired by patching without the use of formwork. An example of patching a concrete superstructure is shown in Figure 11.13. Note that overhead shallow repairs should be avoided, particularly those that do not engage existing rebar or aren't mechanically anchored. Examples of these situations include areas over traffic, over parking, and over pedestrians.

Figure 11.13 Patching of Concrete Superstructure (Courtesy of the New York State DOT)

Figure 11.14 shows the lower portion of a concrete superstructure ready for patching. The white blocks are cathodic protection elements. Cathodic protection is covered in Section 13.1.6 of this manual. The wood forms are in place in Figure 11.15. The final repaired girder section with forms removed is shown in Figure 11.16.

Figure 11.14 Concrete Superstructure Ready for Patch (Courtesy of Washington DOT)

Figure 11.15 Concrete Superstructure with Wood Form (Courtesy of Washington DOT)

Figure 11.16 Completed Repair of Concrete Superstructure (Courtesy of Washington DOT)

Suggested Procedure

Concrete Patch for Superstructure Members

1. Remove any loose concrete in the area to be patched.
2. Sawcut the perimeter of the removed concrete region in straight lines to a depth of ¾ inch to make a clean patch line. If possible, bevel the sawcut at 45 degrees inward to lock the patch in place.
3. Clean the surface of the existing concrete using hand tools, sand blasting and compressed air.
4. Thoroughly wet the concrete surface and allow it to dry on the surface.
5. Mix the patch mortar in accordance with the manufacturer recommended specification for vertical or inverted patches.
6. Apply a bonding agent to the existing surface, but note that all states do not require a bonding agent. Do not let the bonding agent dry before the patch material is placed. (Follow the manufacturer instructions on bonding agent).
7. Use a trowel to firmly apply the patch material into the void created by the spall.
8. Use trowels to sculpt the member shape and texture the finish.
9. Spray apply a curing compound or wet cure for 7 days over the patched area, unless latex-modified concrete patch material is used.

The most permanent patch product for Portland cement concrete is Portland cement concrete. The closer the physical properties of the patch material are to the existing material, the better the patch will perform. Minimize the shrinkage of the patching material by limiting water to cement ratio when mixing. The inclusion of latex in a concrete or mortar will help reduce the amount of water required for workability and also reduce the permeability of the patch. Latex-modified or silica-fume concrete is recommended for vertical and inverted concrete patches due to their enhanced bond strength and cohesiveness. Other concrete additives can be used to reduce setting time and increase strength. For thin patches, the aggregate can be adjusted in the mix design.

11.4.2.2 Recasting with Concrete

Larger concrete superstructure areas can be effectively repaired by replacing the damaged or deteriorated area. Recasting concrete requires formwork and is common for larger beam repairs. Examples of this repair are shown in Figure 11.17 (during) and Figure 11.18 (after).

Figure 11.17 Forming Repair. Pumping Concrete into the Form (Courtesy of the Alberta Ministry of Transportation)

Figure 11.18 Completed Form Repair

Suggested Procedure

Recasting

1. Consult an engineer to determine if there are any structural capacity concerns from removing unsound concrete to the depths and limits necessary for the repair. Place any required temporary shoring or bracing necessary to support the structure during the repair.
2. Sawcut the perimeter edges straight to a depth of ¾ inch. Remove any loose concrete in the area to be patched. Concrete should be removed 1 inch all around exposed rebar whenever possible.
3. The existing surface should be cleaned by light sand-blasting. The concrete surface should be saturated with water spray, if dry, and then allowed to return to a surface dry condition. This will prevent the old concrete surface from absorbing the new concrete mix water. (Continued on next page).

Suggested Procedure

Recasting Procedure (Con't)

4. Install the concrete formwork. The formwork should be rigid enough to prevent new concrete from sagging away from the existing concrete under the weight of new concrete. The formwork should withstand forces from concrete pumping and the vibrating used to consolidate the concrete. Plywood is often used for concrete formwork. Steel forms can be used but they are heavy and not easily handled. Forms are typically attached to the member being repaired or hung from the structure and should be well constructed to prevent leakage of the patch concrete.
5. Prior to placing the concrete, the forms should be cleaned, sprayed with a form release agent and wetted to prevent absorption of the water used in the concrete.
6. Apply a bonding agent (usually a cement grout) onto the concrete surface just before the installation of formwork. It is very important that the bonding grout does not dry out before the repair concrete can be placed. A dry bonding grout can destroy bond of the new concrete to the existing concrete. For this reason many owners do not allow bonding agents. The use of specially formulated polymer bonding agents may be required if the formwork cannot be placed before the grout will dry.
7. Place the new concrete through holes in the top of the formwork for vertical patches if the top is not accessible. Inverted patches should be cast from above if possible through fill holes in the member. If inverted patches cannot be recast from above consider using the shotcrete repair method. Concrete for recasting should easily flow and fill all the voids in the form. Typically 3/8 inch course aggregates are used in the mix to improve flow and consolidation. Limit the water to cement ratio to avoid shrinkage cracking of the repair. Concrete additives may be used to provide workability without resorting to adding additional water.
8. Internally vibrate the newly placed concrete through the fill holes in the forms or by vibrating the forms from the outside. Vibration should be done along the length of the repair after shallow lifts of concrete have been placed. Good compaction is achieved by placing the concrete in small amounts and vibrating effectively as the work proceeds. An option to vibration is to use self-consolidating concrete which does not need any vibration.
9. Allow the concrete to cure.
10. Remove the form work and grind off any excess concrete or fill any voids that formed.

11.4.2.3 Prepacking Dry Aggregates and Grouting

This repair method is very similar to recasting. The surface preparation and formwork is basically the same as those for recasting concrete. The only difference is that a uniform size dry aggregate is packed in the space behind the form so that it fills the space completely. Grout is then pumped from the lowest to the highest point to fill the space between the aggregate, as shown in Figure 11.19. An advantage of prepacking dry aggregate and grouting is that the overall shrinkage of the repair is greatly reduced.

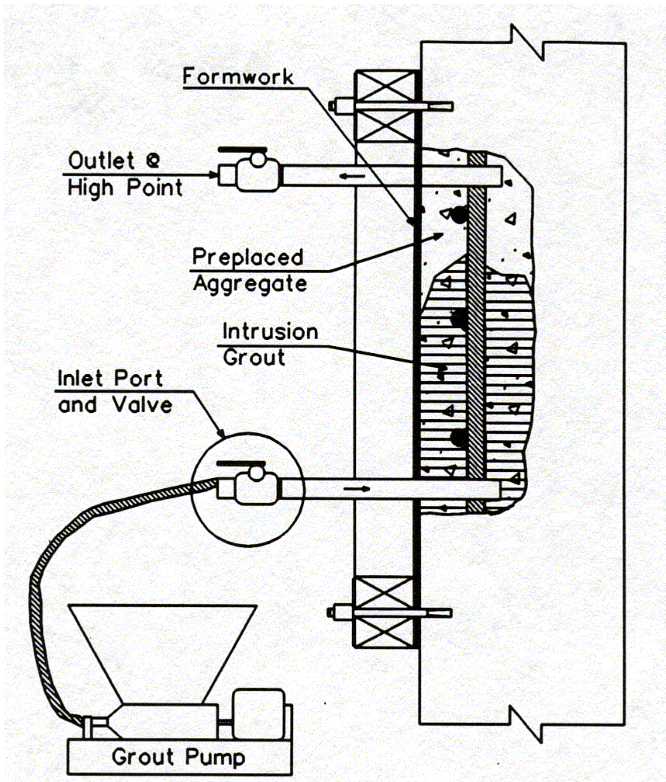


Figure 11.19 Repairing with Dry Aggregates and Grout

11.4.2.4 Shotcrete Repair Method

Shotcrete, or pneumatic applied mortar, is used to repair and restore the surface of concrete bridge elements. It is conveyed through a hose and nozzle and pneumatically projected at high velocity onto a surface. It contains the same cement, aggregate and water as concrete except that there are no course aggregates in the mix. Compaction is achieved by the velocity of the mixture when applied. Shotcrete repairs require a highly trained operator to obtain long lasting results. Many bridge owners require submission of operator qualifications and test panels prior to starting work.

The mix has high cement content and low water/cement ratio. The addition of silica fume, fly ash and/or slag can enhance the performance of shotcrete. Steel or synthetic fibers have also been used to increase tensile strength and decrease the potential for cracking. When properly applied, the mortar is dense, durable, and has superior bonding characteristics.

Shotcrete is desirable on vertical and overhead patches because no forming is required and the pneumatically applied mortar can repair large surface areas in relatively short periods of time. The shotcrete may need to be anchored to the existing reinforcement with additional rebar, wire mesh or mechanical anchors. Shotcrete should not be used for repairs of less than 1 inch thick. A photographic example of shotcrete repair is shown in Figure 11.20, and a procedure for shotcrete repair follows.

Figure 11.20 Shotcrete Application

Suggested Procedure

Shotcrete Repair

1. Preparation of the existing surface is an important part of the repair. The edges of the repair area should be sawcut at least ¾ inch deep at a 45 degree angle into the repair area to prevent rebound of the shotcrete material. All deteriorated concrete should be removed to a minimum of 1 inch behind exposed reinforcement. All surfaces should be cleaned with high pressure water or by sand blasting.
2. For repairs 3 inches or deeper, welded wire fabric or wire mesh should be mechanically affixed to the existing concrete surface prior to the placement of the shotcrete. The wire mesh will help insure the integrity of the repaired area and limit cracking.
3. The existing surface is wetted so it will not absorb water from the pneumatic mortar.
4. Apply the shotcrete. A thin bond coat should be applied first with subsequent layers building up the desired thickness. When applying, place the shotcrete nozzle at 90 degree angles to the repair surface whenever possible. Corners should be applied at a 45 degree angle to prevent rebound. Maintain a uniform flow of material and limit the layer thickness to prevent sags or sloughing to occur. The natural handgun finish is preferred from bond and durability standpoints. Scraping or cutting may be used to remove high points and material that has exceeded the limits of the repair after the mortar has become still enough to withstand the pull of the cutting device. Troweling or other surface finishing is discouraged as it has a tendency to disturb the bond.
5. Curing is very important for the rich mixes and thin sections used with pneumatic mortar. Seven days of water curing is generally advisable to promote good hydration of the cement, keep the mortar cool in hot weather, and prevent early shrinkage that may disturb the bond.

11.4.3 Epoxy Injection Crack Repair

Cracks that develop in concrete superstructure elements can be effectively repaired using epoxy injection techniques. Epoxy injection techniques are well suited for cracks caused by a variety of stresses, but not cracks caused by corrosion of reinforcing steel. Epoxy repairs are typically recommended for crack widths of 0.002 inches or wider. An example of a completed repair is shown in Figure 11.21. Detailed procedures for epoxy injection are provided in Chapter 5.

Figure 11.21 Completed Epoxy Crack Repair

11.4.4 Beam End Repair Procedure

Reinforced concrete beam ends can experience cracking and spalling near the bearings from leaking joints that cause corrosion, freeze thaw damage, or from thermal forces that develop when the bearings do not allow adequate movement. An example of beam end deterioration is shown in Figure 11.22.

Figure 11.22 Beam End Deterioration

A procedure for reinforced beam end repair follows below. It can also be applied to prestressed beams, as long as an engineer is consulted.

Suggested Procedure

Reinforced Concrete Beam End Repair

1. Restrict the vehicle loads on the affected beam by directing traffic to the far side of the bridge until repairs on the beam end are complete.
2. Determine if the existing substructure can be used to jack the bridge up or if a jacking bent will need to be constructed. The jacking supports and jacking procedure should be reviewed by an engineer before any lifting begins.
3. Place jacks and raise the entire end of the bridge a quarter of an inch (Figure 11.23). The lift should only be enough to take the load off and to allow a piece of sheet metal to be inserted on the beam seat as a bond breaker for the new concrete. Check with engineer if this step is necessary
4. Sawcut the concrete edges in a stepped fashion to avoid feathered edges and to provide bearing surfaces for the new concrete (see detail in Figure 11.24).
5. Remove the deteriorated concrete in steps.
6. Epoxy inject any visible cracks not within the removal limits following the epoxy injection procedure in this section.
7. Place new reinforcement as needed, making sure it is properly lapped, anchored, or mechanically attached to the existing steel. Bars can be welded to the existing longitudinal bars as shown in Figure 11.24.
8. Clean repair using abrasive blast cleaning.
9. Apply epoxy bonding agent to prepare the surfaces of the beam end. If agency does not allow a bonding agent, bring surface to saturated surface dry condition.
10. Place the forms for the new concrete. Place the new concrete. A non-shrink additive should be used in the new concrete.
11. After the concrete has reached sufficient strength, jack all beams simultaneously to sufficient height to allow the new bearings to be placed or to reinstall the old bearings.
12. Uniformly lower the end of the bridge. Check for possible distress in the repaired area.
13. Remove the jacking system.

Figure 11.23 Beam End Repair Preparation

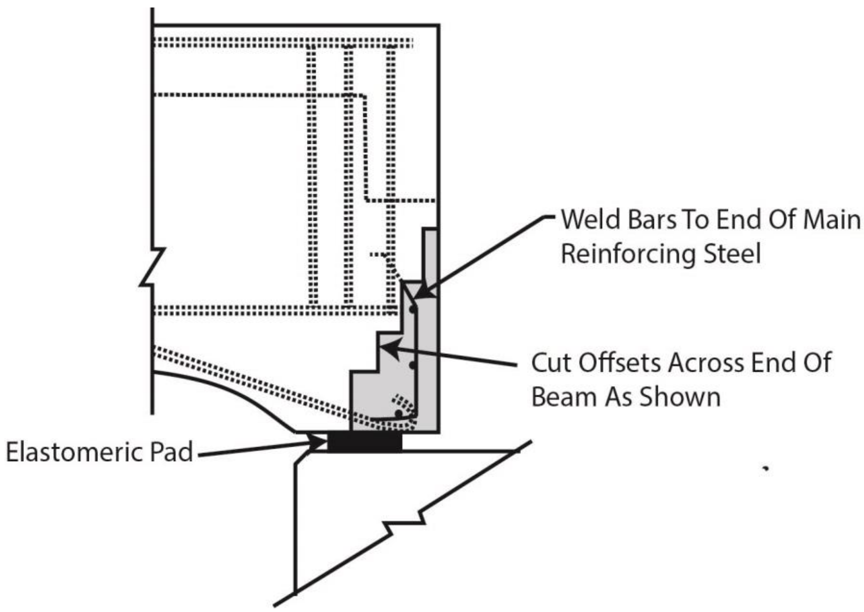


Figure 11.24 Detail of Repaired Beam End

11.4.5 Fiber Reinforced Polymer Repair

The flexural and shear strength of concrete superstructure members can be increased or restored by applying externally bonded fiber reinforced polymer (FRP) strips that supplement the tensile steel within the member. An example of this procedure is shown in Figure 11.25. This repair method can be highly effective in restoring strength in beams, stringers and floor beams that have lost strength due to cracking or loss of reinforcing steel caused by impact or deterioration. It has been successfully used as a preventive maintenance application for the beam ends of precast prestressed concrete girders.

The FRP strips are typically bonded to the bottom of beams in areas of high tension or the sides of beam webs in high shear areas. An engineer should determine the location, number and width of FRP strips to be placed. Once the number and placement of the FRP layers has been determined, the FRP can be applied. A suggested procedure for FRP application follows:

Suggested Procedure

FRP Application

1. Remove any unsound concrete that is within the area the FRP is to be applied.
2. Cracks wider than 0.010 inches wide should be filled with epoxy resin following the epoxy injection procedure in this section.
3. The concrete surface should be thoroughly cleaned using abrasive hand tools or blast equipment. The surface should be blown clean with compressed air.
4. The FRP should be cut to the size with heavy shears as specified by the engineer and in accordance with manufacturer's recommendations.
5. Prime the clean and dry concrete surface with epoxy resin using a trowel. The primed area should exceed the FRP size by approximately one half inch on all sides. Allow the epoxy to become tacky.
6. Prime the surface of the FRP to be placed on the concrete.
7. Place the FRP strips on the primed concrete such that the epoxy primed sides stick together epoxy to epoxy (Figure 11.25).
8. Use a rubber roller to press the FRP flat and smooth on the concrete.
9. Allow the epoxy resin to fully cure.

Figure 11.25 Applying FRP to Strengthen a Beam

11.4.6 Repairing Deteriorated or Damaged Reinforcing Steel

Concrete superstructure elements are typically reinforced with conventional reinforcement (rebar) or prestressing strands. The reinforcement can sustain section loss due to corrosion or can be damaged from vehicular impact. The repair techniques used to restore the reinforcing varies depending on whether the steel is stressed or not.

Conventional Rebar

When performing concrete repairs, it is important to protect the existing steel reinforcement. Incorporating the existing reinforcement into the new repair material will lengthen the service life of the repair. Steps to incorporating the existing reinforcement include:

- Locate existing reinforcing steel
- Remove unsound concrete from around reinforcing steel
- Assess damage to existing steel
- Clean
- Incorporate into repair

Locating the existing reinforcing steel is very important. If the concrete removal is started without knowing the depth of concrete cover over the steel, damage to the steel could result. There are non-destructive testing methods, such as using a pachometer, that determine cover depth.

Unsound concrete should be totally removed from the perimeter of the existing reinforcing. Concrete needs to properly bond to the reinforcing steel to resist forces. If more than one half of the diameter of the bar is exposed, the entire bar should be exposed including the underside. The underside removal could be determined based on the size of the aggregate of the repair concrete, but usually a 1 inch clear cover is needed. Concrete removal or existing corrosion may reduce the cross sectional area of the reinforcing bar to a point where it should be totally removed and replaced. That can be determined with the aid of an engineer.

Reinforcement bar cleaning is essential for concrete bond. This includes removal of rust and chlorides from the steel to inhibit future corrosion. Ways to accomplish this for bridge superstructures include wire brushing or sand blasting.

Once bars are cleaned they can be incorporated into the new repair. If supplemental reinforcement is needed to replace damaged or deteriorated bars, the new bars should be connected to existing reinforcement with proper lap lengths or mechanical connections. A lap length means the new reinforcement is placed side by side with the existing for a predetermined length decided by the bar size. Most agency specifications provide these lengths. If the patch is not large enough for a full lap length, mechanical bar splices can be used.

Prestressed Strand Splicing

Girders with significant deterioration or damage from truck impacts have been successfully repaired using the spliced strand technique. The area requiring a strand splice must be away from bearing areas and strand hold-down points. The strand to be spliced must be anchored beyond the repair area so that the re-stressing force can be attained. The length for anchorage needs to be confirmed by the engineer and is called the strand development length. The equipment for splicing strands will not easily accommodate abrupt changes in strand profile limiting the use of this technique to areas where the strands are relatively straight.

The strands in prestressed concrete members have been tensioned, effectively squeezing the concrete and placing it in compression. The tendons place sufficient compression in the concrete to prevent the section from going into tension when the bridge is loaded.

Cracks in prestressed concrete and corrosion of the strands are concerns. Since the tension is high in the tendons, the loss of a significant amount of concrete can cause the remainder of the section to crush and fail. A single tendon break due to an impact or corrosion will typically only cause a minor effect, however several tendons snapping may cause a sudden failure of the member.

Special sequenced steps are needed when repairing prestressed concrete members to restore the tension that existed in the strand originally. These steps are normally determined by a structural engineer. Tension must be placed back into broken tendons as part of the repair using tendon splices. They are anchored to the ends of the damaged tendon and a threaded coupler nut between the two anchors is torqued a prescribed amount to produce the tension needed in the tendon. It is desirable to maintain the original girder cross-section to maintain headroom below and for girder appearance. The splice hardware has a much larger diameter than the strand, reducing concrete cover and increasing congestion in the repair area. It may be necessary to offset splices to reduce congestion and facilitate concrete placement. Splices generally reduce the fatigue life of the strand and the member. Often times only the slack needs to be removed from repaired broken strands, for example when only a few strands are broken due to an overweight load.

Details showing the removal and installation sequence are presented in Figure 11.26 through Figure 11.30. A prestressed strand splice procedure follows:

Suggested Procedure

Prestressed Strand Splice

1. Consult an engineer to determine if there are any structural capacity concerns from removing unsound concrete to the depths and limits necessary for the repair. Place any required temporary shoring or bracing necessary to support the structure during the repair.
2. Sawcut the perimeter edges straight to a depth of 3/4 inch. Remove any loose concrete in the area to be repaired. Concrete should be removed 1 inch all around exposed rebar whenever possible. The minimum length of concrete removal necessary in order to install all the strand splicing and tensioning devices is approximately six feet (see Figure 11.26).
3. Saw cut the broken strand to remove any frayed or damaged length. Leave at least 4 inches of strand exposed to install the splice devices.
4. Install splice hardware consisting of coupler, stressing gauge and tensioning device (see Figure 11.27 and Figure 11.28). The arrangement for these devices may be changed if it is more convenient.
5. Torque the splice hardware to tension the strand.
6. If a significant amount of concrete is replaced, the compression must be removed from the concrete in the beam around the damaged area. This is done by placing a calibrated load on the bridge while the new concrete is placed and is reaching its design strength. This step is known as preloading the member.
7. Preload member and replace the concrete using one of the techniques outlined in this section.

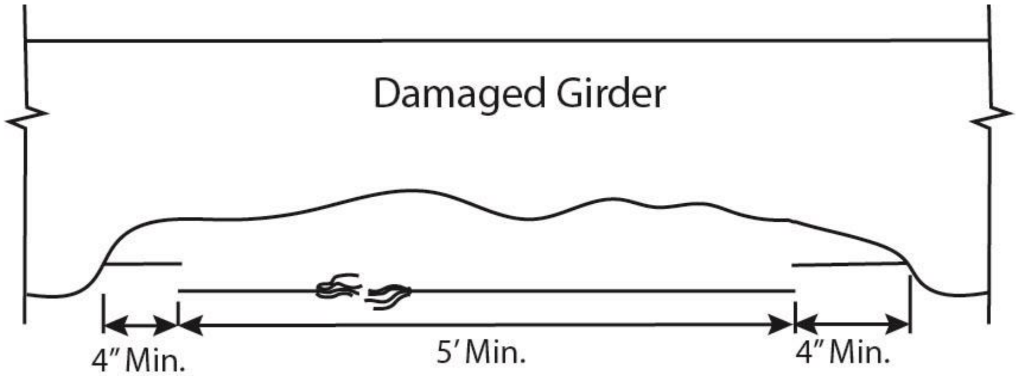


Figure 11.26 Remove Damaged Strand Length

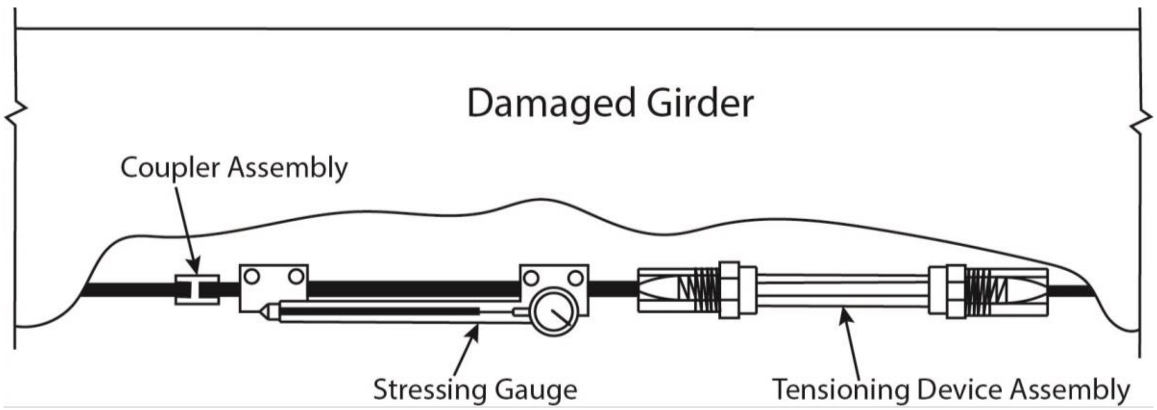


Figure 11.27 Splice Hardware

Figure 11.28 Tensioning the Splice (Courtesy of the Nebraska Department of Roads)

Figure 11.29 Completed Splice Ready for Concrete

An alternative to manually tensioning the splice is utilization of a coupling system. An example of a prestressed girder repair utilizing a coupling system is shown in Figure 11.30.

Figure 11.30 Completed Strand Coupling System in Prestressed Girder Repair

11.4.7 Maintenance and Repair of Adjacent Prestressed Box Beams

Prestress concrete adjacent box beams are a popular superstructure type. The beams are placed directly next to each other and may be connected with poured keyways and possibly transverse tie rods also referred to as post-tensioning. They may be constructed with or without a reinforced concrete deck cast-in-place over the beams. These beams can have issues with premature deterioration due to cracking and other maintenance issues depending on the construction details. Figure 11.31 shows the underside of an adjacent box beam bridge with significant water leakage between the joints which deteriorates the concrete. Maintenance recommendations have been provided in documents such as NCHRP Synthesis 393, *Adjacent Precast Box Beam Bridges: Connection Details*. According to research, the predominant distress observed in these bridges is reflective cracking of the slab along the shear keys between beams and the associated degradation below the cracks.

Figure 11.31 Underside of Adjacent Box Beam

Some potential preventive maintenance options for adjacent box beam bridges include

- Sealing the deck
- Removing the asphalt topping
- Sealing the cracks
- Washing the decks on an annual basis
- Unclog drains (see Figure 11.32)

Some potential repair options include

- Add a reinforced concrete deck
- Add supplemental transverse tie rods (post-tensioning)
- Replace the asphalt wearing surface with a concrete deck
- Use waterproofing membrane over the entire surface and reseal the deck

Note that these preventive maintenance or repair options are dependent upon whether the existing bridge had a poured concrete deck or not.

Figure 11.32 Clogged Drains are an Issue

11.5 Repair and Rehabilitation of Steel Superstructures

11.5.1 Introduction

Modern steel bridges typically require fewer steel superstructure repairs than older structures due to their shorter time in service; use of modern corrosion resistant steels with improved toughness; utilization of continuous superstructures with fewer deck joints or jointless bridges; absence of fatigue prone details and proper design to resist fatigue, "maintenance free" or low maintenance design and detailing of built-up members; adequate vertical and horizontal clearances reducing a potential for vehicle impact damage.

Hence, the majority of the steel superstructure repairs are performed on older bridges due to the following reasons:

- Many multi-span bridges have simple span superstructures with a large number of leaking deck joints
- Failure of the aging steel coating system
- Inadequate bridge drainage infrastructure – free drop spraying or clogged old downspout system
- Stress related fatigue in superstructures designed prior to 1974 and distortion induced fatigue in superstructures designed prior to early 1980's
- Many bridges are functionally obsolete due to low vertical under clearance and are susceptible to under passing vehicle impact damage, as well as narrow horizontal clearances on some through trusses, which can also lead to impact damage
- Corrosion occurs from roadway and high water debris collection on superstructure members, truss joints, beam seats, and around truss member penetrations through decks or sidewalks

Steel superstructure repair usually involves some type of welding and/or bolting. Both methods are discussed in Sections 13.5.1 and 13.5.2 and are also referred to many times within this chapter.

11.5.2 Corrosion and Section Loss

Section loss from corrosion is a common type of a steel superstructure damage that routinely requires maintenance repair. It often occurs at the girder ends under leaking deck joints and at the "pockets" of built up member connections, bottom flanges, and framing members that act as a shelf and trap debris.

11.5.2.1 Corrosion Damage at Girder Ends and Example Repair Procedure

Joint leaks over girder and stringer ends subject those areas to repeated moisture which degrades the steel coating and leads to corrosion and section loss. It typically affects the lower portion of girder ends, bearing stiffeners, and end diaphragms. See Figure 11.33 below for an example of girder end corrosion damage before (left) and after (right) sandblasting and primer application. After removing the corrosion product by sandblasting and priming, repairs can be performed.

Figure 11.33 Corrosion Damage at Girder Ends (Concrete Deck has been Removed)

When to Call the Engineer

Call the Engineer for plans and details regarding girder repairs.

A typical girder repair procedure is presented below.

Suggested Procedure

Girder Repair

1. Remove the paint within the limits of repair
2. Disconnect and remove existing end diaphragm(s) as required
3. Remove girder bottom flange to bearing welds by grinding
4. Jack the stringer 1/16 inch maximum and install temporary blocking
5. Remove deteriorated portion of the stringer to the required limits
6. Cut a tee or full section from a matching W section
7. Weld or bolt new tee section to replace the removed damaged portion of the stringer end or splice new full section using bolted splice connection. The choice of bolting or welding could be based on owner's requirements and environmental factors.
8. If bearing stiffeners were removed as part of the process, as shown in Figure 11.35 (left), the Engineer should be consulted to address how to replace them, if replacement is needed
9. Perform NDT (UT) testing and repair all weld flaws as required
10. Re-jack, remove blocking and lower the stringer onto the existing bearing
11. Field drill holes in the repaired stringer web and re-connect the existing or replacement end diaphragms using high strength bolts
12. Re-weld the girder bottom flange to the bearing sole plate
13. Clean and paint all steel surfaces disturbed by the repair

See Figure 11.34 and Figure 11.35 for representative examples of the above repairs.

Figure 11.34 Example of a Girder End Repair Utilizing Bolted Splice of a New Full Section

Figure 11.35 Repair in Progress using Tee – Section Cut Out From a Matching W Section

11.5.2.2 Repair of Built Up Members

Many older bridges have built up I-shaped steel girders, floorbeams, and other members that are typically comprised of plates and angles riveted together. An example drawing of a built up I-shaped steel girder is presented in Figure 11.36. This type of girder often traps debris between the rivets, stiffeners and on the top of beam flanges. The moisture and debris can come from leaking joints, inadequate scuppers, spray from vehicles, or bird droppings. The moisture and debris can lead to a failure of the protective coating, corrosion and ultimately section loss as shown in Figure 11.37.

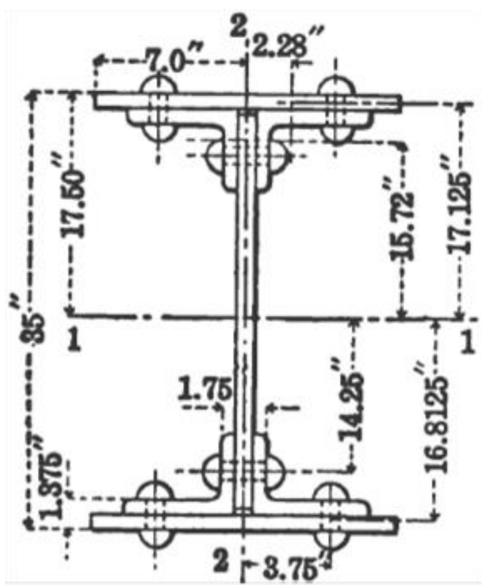


Figure 11.36 Typical Built-Up I Shape

Figure 11.37 Example of Heavy Corrosion and Section Loss

When to Call the Engineer

To assure the repair will restore the member to the desired capacity, an engineer should be consulted for design and detailing.

Highway overpass superstructures are particularly prone to moisture and debris accumulation carried by vehicle spray. While built up riveted members may be less forgiving, rolled members are also subject to corrosion from the same processes.

In cases where the section loss is minor and not significantly decreasing the capacity of the member, sand blasting and painting the area to arrest continued corrosion and section loss is often the chosen repair. In cases where section loss is significant and adversely affects the girder capacity, additional cover plates or angles may be added to restore the section as shown in Figure 11.38. To assure the repair will restore the member to the desired capacity, it should be designed and detailed by an Engineer.

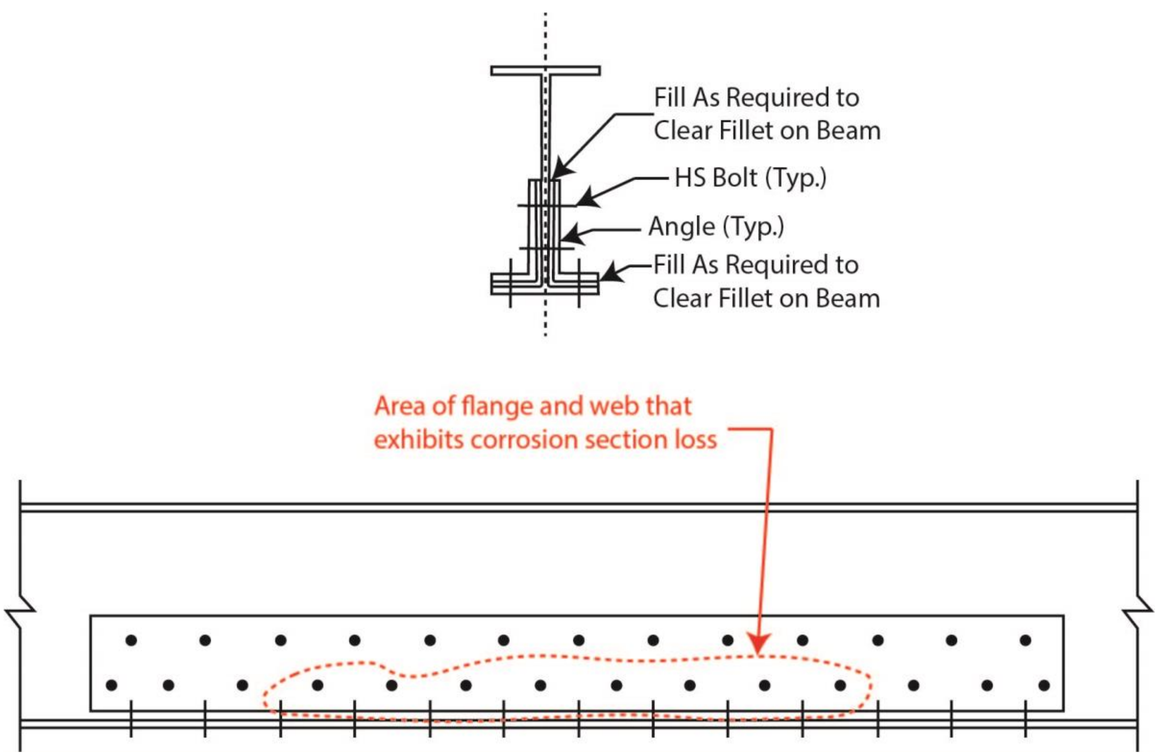


Figure 11.38 Sample Girder Repair Detail

The photographs in Figure 11.39 show a girder repair made by the OBPA Maintenance Personnel (courtesy of the Ogdensburg Bridge and Port Authority (OBPA)).

Figure 11.39 Girder Repair. Before (left) and After (right).

Crevice Corrosion

Crevice corrosion between the cover plates and other elements of built-up members (particularly riveted members) is not uncommon. It often causes plate distortion and buckling, and sometimes even leads to rivet failure. Examples of crevice corrosion are shown in Figure 11.40, which are built up box members without top plate (left) and with top plate (right).

Figure 11.40 Built Up Box Member Corrosion

In most cases, plate replacement is required. Sometimes if the distortion is relatively minor, a power tool cleaning using a needle scaler and/or wire brush, followed by sealing and painting will slow the progression of corrosion. This type of repair is not permanent, so continued monitoring and maintenance will be necessary.

11.5.2.3 Repair of Truss Members

Primary Compression and Tension Truss Members

The repair of primary compression and tension truss members can be complex. It may require special access and substantial bracing. It should be properly designed by an engineer and performed by experienced agency staff, or a qualified contractor. See Figure 11.41 for replacement of truss bottom chord plate utilizing high strength thread bars and jacks for the load transfer and stability.

Figure 11.41 Repair of Bottom Chord Plate (left) Utilizing Thread Bars and Jacks (right)

Primary members smaller than those shown in Figure 11.41 may also be repaired with the addition of cover plates and angles, similar to the repairs shown in Figure 11.38.

When to Call the Engineer

Whenever work is being performed on truss members, an engineer should be called to determine the extent of temporary bracing needed.

Secondary Members

The repair and replacement of secondary members such as bracing is typically less complex than that of primary members, but still requires a detailed procedure and adequate bracing to provide for overall stability of the truss during repairs. See Figure 11.42 for an example of secondary member replacement.

Figure 11.42 Replacement of Bracing and Connection Plate. Before (left) and After (right)

Lacing Bars and Batten Plates

Lacing bars and batten plates were commonly used in older riveted structures for the webs of I-shaped built-up members or the sides of box sections. Batten plates can be used in combination with the lacing bars and may be located at ends of built up members. They can have a rectangular or U-shape to accommodate connections to other members.

Deteriorated or otherwise damaged lacing bars and batten plates can typically be safely removed and replaced in kind one at a time, following the procedure similar to the rivet replacement procedure provided in Section 11.5.2.4.

See Figure 11.43 for an example of a batten plate replacement detail.

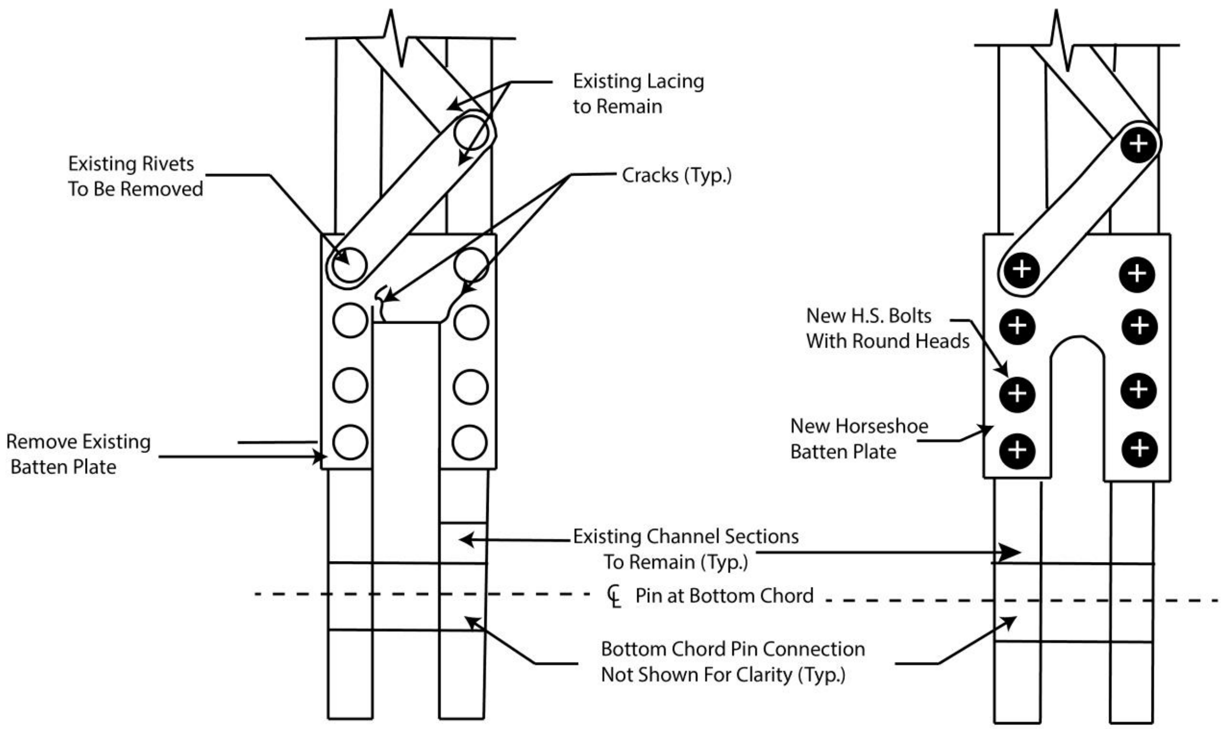
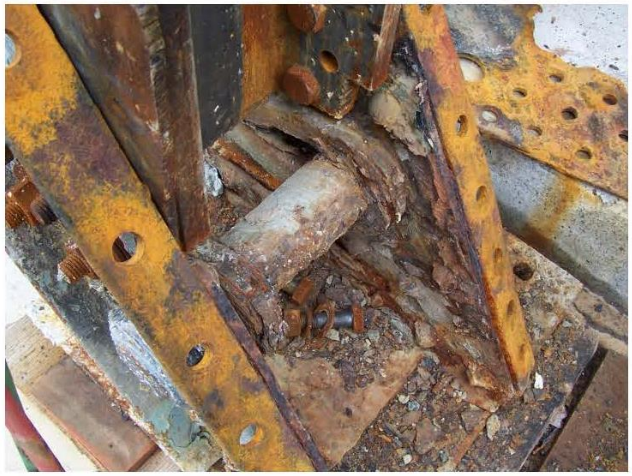


Figure 11.43 Batten Plate Replacement Detail

Repair of Truss Member Ends

Repair to the ends of steel truss members is a very common repair since these members are in close contact with salt and other contaminants on the bridge deck surface and because debris and moisture collect in congested end sections. This repair requires a sequence of events to properly remove, replace, and/or repair members.

After temporarily supporting the connection, deteriorated members such as the pin, eyebars and gusset plates are removed, an example of which is shown in Figure 11.44. More specifically, Figure 11.44 shows (a) Pin and gusset plate replacement required due to severe corrosion and (b) New pin installed and gusset plate ready for installation.



(a)

(b)

Figure 11.44 Corroded Truss Member End Repair

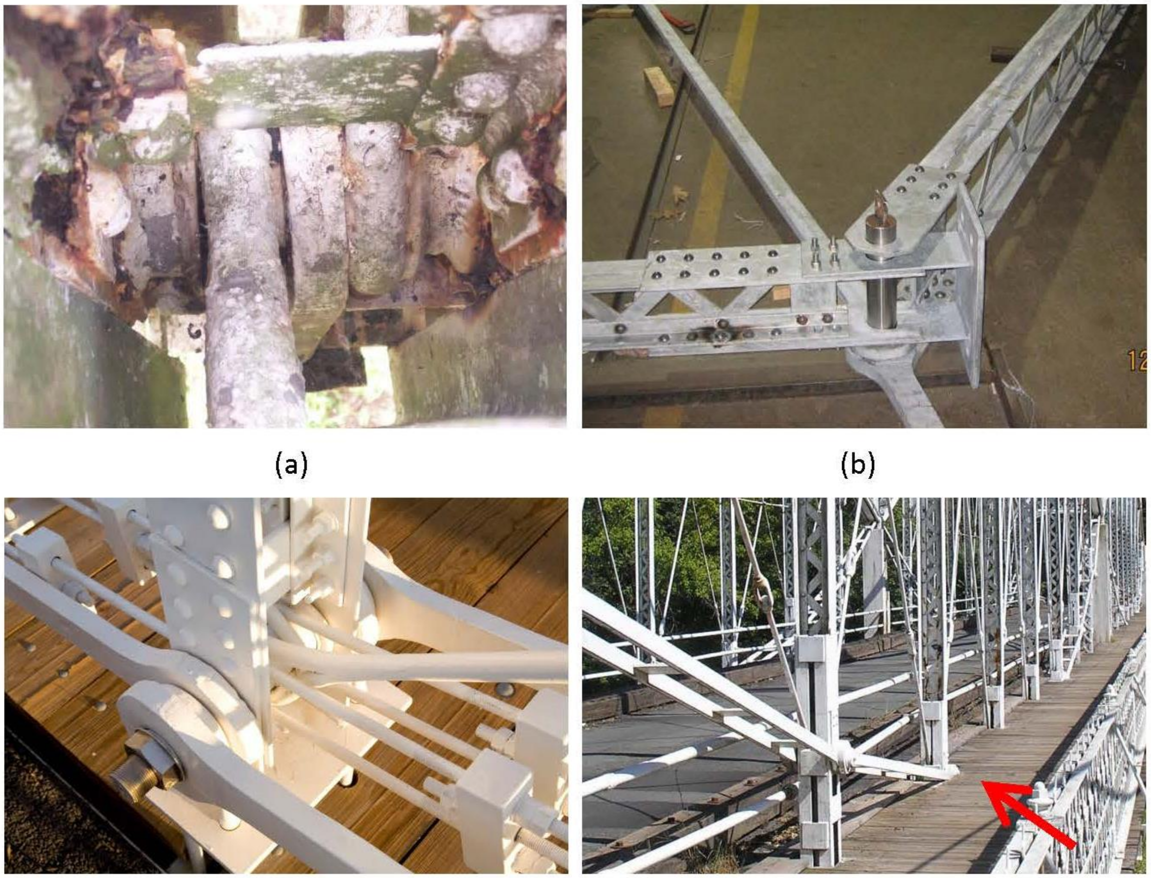
In the replacement shown in Figure 11.45, pin and gusset plate are added. The eyebars were not replaced, but removed, repaired, and repainted.

(a)

(b)

Figure 11.45 Representative Corroded Truss Member End

In a third truss member end repair example shown in Figure 11.46, before and after photos of the eyebars and entire repair are shown. Specifically shown are (a) Corroded pin and eye bars, (b) Installation of new pin, eyebars cleaned and repainted (c) The repaired assembly is painted, (d) Representative location of repair (shown by arrow).



(a) (b) (c) (d)

Figure 11.46 Truss Member End Repair

Repair of Primary Truss Members near Bearing

As stated earlier, the repair of primary compression and Tension truss members and their connections must be properly designed by an engineer and performed by experienced agency staff or a qualified contractor. Repairs will usually require substantial bracing and temporary supports if any parts of the primary members are being removed. These repairs can become more complex when they are in the vicinity of the bearings.

Figure 11.47 is a repair of the bottom chord near the bearing. This repair would require bracing, external support, and an engineered design. If repairs were being done on the pin or connection plate that attach the bottom chord to the diagonal member, that repair would require an even greater amount of bracing and shoring to remove the loads while the repair was being performed.

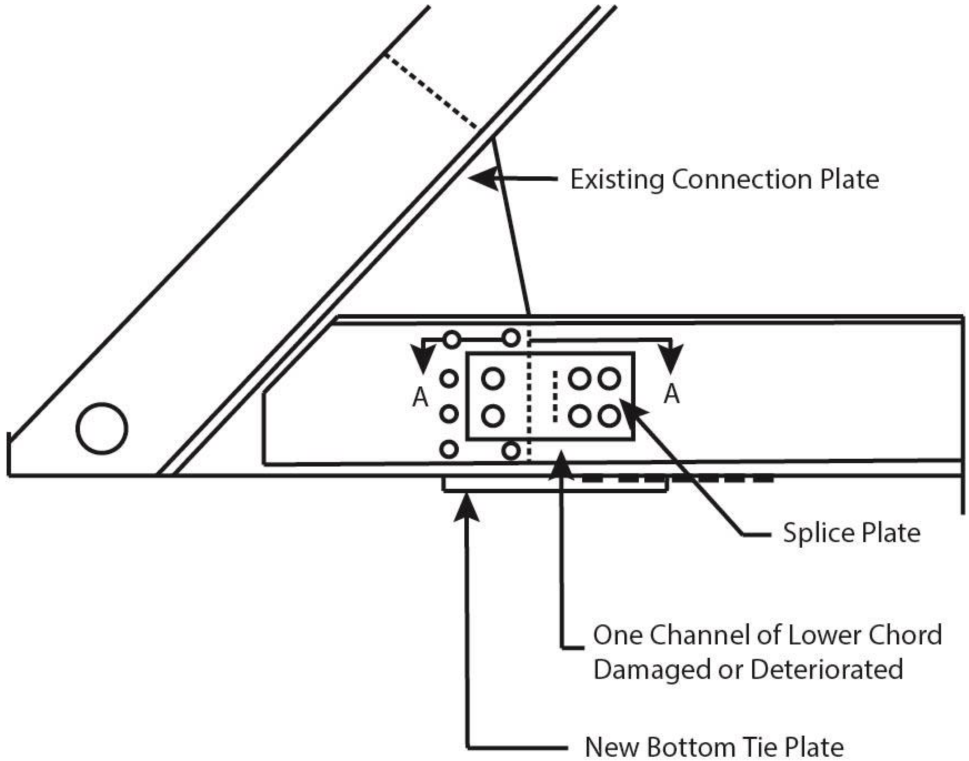


Figure 11.47 Schematic for Primary Chord Repair Near the Bearings

Bolted Splice Repair: Adding Doubler/Splice Plates

Another technique that can be used to repair corrosion loss and some types of cracks is doubler or splice plates, hereafter referred to as doubler plates or doublers. Doubler plates add material to either increase a cross-section or provide continuity at a deteriorated or cracked cross-section. For corrosion loss, the plates simply add enough steel cross section to make up the cross sectional loss. This technique can work as well for fatigue cracks to reduce stress range by allowing the plates to take the stress away from the cracked steel.

A consideration when using this repair for cracks is that the cracks will no longer be visible for inspection when plates are place on both sides of the repaired area. Although this repair is intended to prevent future crack growth, an engineer is needed to determine if crack propagation could be an issue and if this is the appropriate repair.

One problem with this type of repair can be maintaining the alignment of the two sides of the cracked section prior to the repair. The cracked surface may be buckled, making alignment difficult. Doubler plates should then be designed with the ability to straighten out any buckles in addition to providing added strength. The design process is identical to that used for a bolted field splice connection.

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When to Call the Engineer

An engineer will be needed to design a bolted doubler/splice plate retrofit.

Doublers can be attached by welding or by using high-strength bolts. From a fatigue-resistance standpoint, bolted doublers are always better than welded, because a high-strength bolted connection can be considered an AASHTO Category B fatigue detail. A welded connection will most likely result in a Category E condition or worse. As a result, this manual recommends specifying only bolted doubler connections.

Suggested Procedure

Bolted Doubler/Splice Plate Retrofit

1. Align both sides of the crack if there is gross deformation
2. If there is a crack in the steel, drill out crack tip with a minimum 1.0 inch diameter hole to cease crack growth. A larger hole may be required to ensure you remove the crack tip, which is especially important because the repaired area cannot be subsequently inspected for crack growth.
3. Determine the required cross-sectional area of the doublers depending on whether the doublers will be intended to reduce stress ranges, restore a cracked section or corrosion loss. An engineer is needed.
4. Fabricate the doublers with all the holes drilled for bolted retrofits. In the field, clamp one of the doublers against the surface it will be attached to and use the doubler as a drilling template. Drill all holes in the cracked structure.
5. After all holes are drilled, remove the doublers and clean all contacting surfaces to remove oil, grease, dirt, and cutting fluids to restore the friction surface of the slip-critical connection.
6. Reposition the doublers and fill all the holes with high-strength structural bolts. Initially snug tighten all the bolts making sure all surfaces are mated. Use turn-of-nut method to fully tension all the bolts after the snug tight operation, or use tension-controlled bolts. See turn-of-nut requirements published by the Research Council on Structural Connections and Chapter 13 of this manual.
7. Prime and paint the bare surfaces. Document the location and repair procedure for inclusion in the bridge file for use in future inspections.

Figure 11.48 shows the completed Bolted Splice Repair.

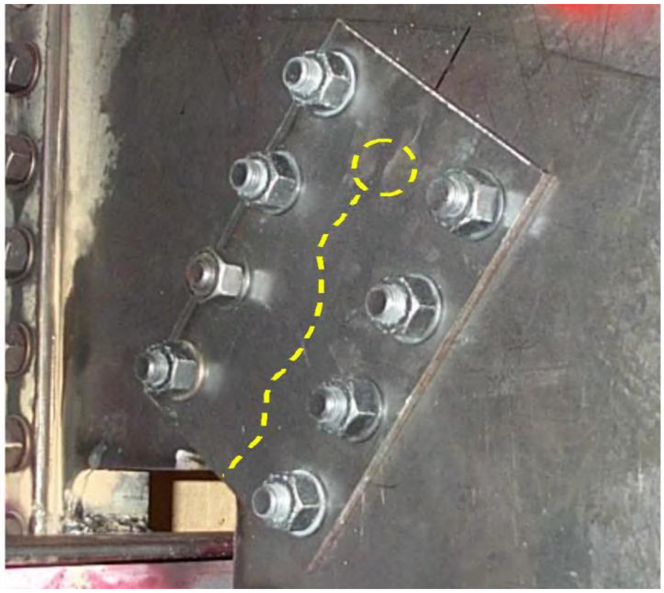


Figure 11.48 Completed Bolted Splice Repair

For more of these types of retrofits, please reference FHWA Publication FHWA-IF-13-020 *Manual for Repair and Retrofit of Fatigue Cracks to Steel Bridges*, March 2013.

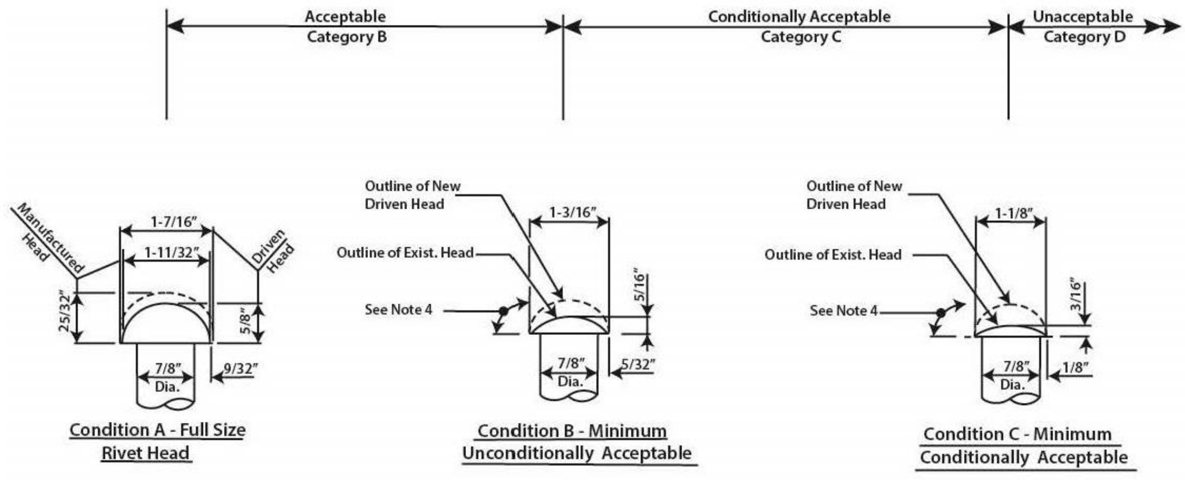
11.5.2.4 Rivet Replacement

Built up members and connections often exhibit corrosion of rivet heads requiring their replacement. An example of corroded rivet heads is shown in Figure 11.49.

Figure 11.49 Rivet Heads Exhibiting Various Degrees of Corrosion

Rivet acceptance and replacement criteria varies between various agencies and Bridge owners. Rivets (even at the same connection) often have various degrees of head deterioration and volume loss. The question is: how much of the rivet head metal remaining is “enough” for the rivet to perform as intended and provide for the connection capacity before it shall be removed and replaced?

Figure 11.50 is a drawing of rivet acceptance criteria for 7/8 inch diameter rivets from the New York State Department of Transportation. These criteria were used on some projects and are offered here as guidance. The figure outlines a new rivet head shape (dashed line) versus actual (remaining) rivet head that shall be field measured (solid line) and qualifies if the rivet should be considered for replacement. It divides rivet head conditions into 4 categories ranging from New to Unacceptable with corresponding qualifier notes that describe their acceptance criteria.



Rivet Replacement Criteria for 7/8" Dia. Rivets

Rivet Replacement Notes:

1. Rivets category B with dimensions of both heads meeting or surpassing each of the minimum requirements shown for condition B may be left in place subject to conditions described in notes 4 and 5.
2. Rivets Category C not meeting the requirements of condition B, but having dimensions which meet or surpass at both heads each of the minimum requirements shown for condition C may be left in place subject to the following conditions:

There is no prying action from applied stress or crevice corrosion which tends to separate the connected parts. Rivets' heads do not have additional losses described in Note 4.

Rivets may be left in place to the extent that their number does not exceed 20% of connection rivets in any one connection or 50% of stitch rivets in any one portion of a member.

Where the above percentages are exceeded the number of rivets over the prescribed percentage shall be replaced with high strength bolts. When selecting rivets for replacement to meet the above percentage requirements, the worst rivets in any group or connection shall be selected for replacement.

3. Rivets category D not meeting the requirements of condition C a tether head shall be replaced with ASTM A325 high strength bolts of the same diameter, see Note 8 below.
4. Replacement will also be required for any rivet exhibiting additional loss in the form of pits or gouges at the edge of either head projecting beyond the shank where such loss reduces the section below the limits shown for Condition B.
5. Where crevice or interface corrosion between connected parts is present, the rivets adjacent to that area shall be replaced after cleaning between the parts regardless of the condition of the rivets.
6. Dimensions shown on these sketches for conditions B and C are minimum requirements for both driven and manufactured heads. The minimum height of head is measured to the center of the rivet. The minimum diameter applies to that direction in which it is the smallest.
7. All high strength bolt connections shall be assembled with a hardened washer under both the bolt head and nut. Where necessary washers may be clipped on one side to a point not closer than 7/8 inch of the bold diameter from the center of the washer.
8. Reading to dress up the rivet holes may be required; if after reaming the hole diameter exceeds tolerances the next larger sized bolt shall be installed.

Figure 11.50 Rivet Replacement Criteria for 7/8 inch Dia. Rivets and Notes

Rivets should be removed in a manner that will not damage the underlying connected material by using a pneumatic rivet breaker to shear the head. The shank may be driven out with a pneumatic punch or rivet breaker after shearing the head. If the rivet shanks cannot be removed by punching without damaging the base metal, the rivet shall be removed by drilling as shown in Figure 11.51.

Figure 11.51 Rivet Removal. Pneumatic Rivet Breaker (left) and Drill Removal (right)

One rivet at a time should be removed and replaced with High Strength (HS) Bolts. The replacement bolt should be properly tensioned prior to removal of a subsequent rivet.

When to Call the Engineer

With the consultation of an engineer, possibly more than one rivet can be replaced at a time.

Suggested Procedure

Replacement of Rivets with HS Bolts

Rivet Removal:

1. Break head of rivet with pneumatic rivet breaker, taking care not to damage the underlying metal.
2. Drive rivet shank out of hole using pneumatic punch. If punch will not remove rivet shank, drill rivet out of hole.
3. Remove only one rivet at a time and replace with HS bolt before removing other rivets unless specifically authorized by the Engineer.

Area Preparation:

1. Upon removal of each rivet, the base metal around the hole should be examined for surface irregularities, cracks, and deterioration.
2. All oxidized materials, nicks, and burrs, steel peaks and cusps that would interfere with the seating of the bolt head, nut and washers should be ground off.
3. Encrusted and built-up paint film around the head, nut and washers of new fastener should be removed to bare metal.
4. Where irregularities to the surface of the hole prevent normal alignment of the bolt or insertion of the bolt without damage to the threads, the hole should be reamed such that the holes are perpendicular to the surface.

HS Bolt Installation:

1. Replace rivets with bolts of the same nominal diameter.
2. Replacement bolts should be long enough to result in minimum stick-through of 1/16 inch beyond the nut.
3. Hardened washers should be used under both the head and nut.
4. If an irregular or beveled surface requires the use of a hardened beveled washer under a bolt head or nut, the beveled washer should be used under the element which is not turned. A hardened standard washer shall be used under the turned element.

11.5.3 Fatigue Crack Repairs

Fatigue damage is a structural damage to a steel member or its component resulting from cyclic loading leading to the initiation and propagation of cracks. Fatigue damage typically occurs at stress levels that are significantly lower than the base material yield stress.

Current design criteria and details have evolved to reduce the probability of both load-induced and distortion-induced fatigue damage. However, welded steel structures that were fabricated before early 1980's often used fatigue prone details which are more likely to exhibit load-induced and distortion-induced fatigue cracking that requires a remedy or repair.

An example of a fatigue crack is shown in Figure 11.52. Due to out of plane distortion where the floorbeam connects to the web, the crack most likely initiated at the lower floorbeam flange to web connection.

Figure 11.52 Fatigue Crack

The most common techniques that are used to remedy or repair fatigue cracking include weld grinding, arrest hole drilling, reinforcement plate strengthening and addition of a tee or double angle stiffener to flange connection. There are also other techniques as StopCrackEX bushing technology, peening, and release of connection. Weld Grinding, Arrest Hole Drilling, StopCrackEX bushing technology, and Reinforcement Plate Strengthening are discussed in this chapter.

For more information, please see NHI Course 134062 and FHWA *Manual for Repair and Retrofit of Fatigue Cracks in Steel Bridges*, found at:

http://www.fhwa.dot.gov/bridge/steel/pubs/hif13020/hif13020.pdf

11.5.3.1 Weld Grinding

Small cracks sometimes occur at the toe of a weld. These cracks mostly are due to weld shrinkage of larger size welds. Weld toe grinding and removal of the crack containing portions of these welds will increase the fatigue life of the weld and reduce the risk of crack propagation into the base metal. Weld grinding can be completed using disc or burr grinding depending on the access and preference. Grinding should be performed carefully to avoid creating a notch. The repair area should be tested using Magnetic-Particle Testing (MT) or Dye Penetrant after completion of the repair to verify the crack has been entirely removed.

Identification of which weld cracks can be ground verses repaired should be made by a trained person. Nondestructive testing can help to determine the depth of the crack. If superficial, grinding would be the preferred solution.

11.5.3.2 Drilling Arrest Hole

Drilling a crack arrest hole at the tip of a crack is a common repair method that has been widely utilized as an economical technique for arresting fatigue cracks. An example of the holes drilled by this procedure is shown in Figure 11.53. The size of the drill hole can be calculated by an engineer taking into account the calculated stress levels, thickness of steel and yield strength. However, this is rarely done. Holes are usually drilled at diameter of ¾ inch to 1 inch.

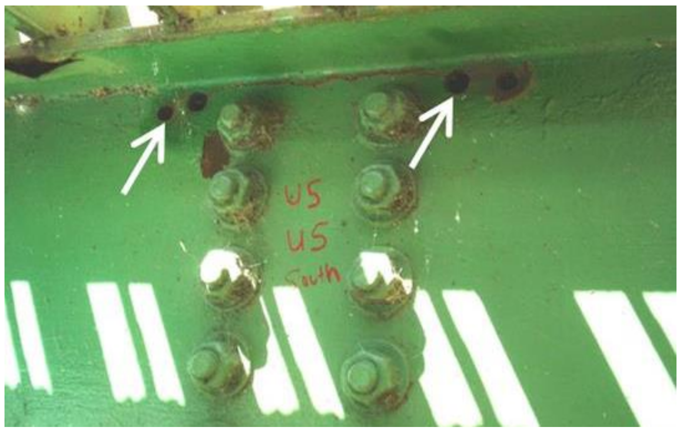


Figure 11.53 Examples of Drilled Crack Arrest Holes

The procedure must be done properly to be effective. The arrest hole should be drilled in front of the crack with the crack tip located between the hole edge and the center of the hole, as shown in Figure 11.54. Nondestructive testing such as dye penetrant testing or magnetic particle should be used to accurately locate the tip of the crack prior to determining the arrest hole location. The crack rarely propagates evenly thru the material thickness and often extends farther on one side of the plate than another. Therefore, dye penetrant testing on both sides of the cracked web allows a more accurate location of the crack tip. However, it may not always be practical or possible to inspect both sides due to limited access or physical constraints. After the hole is drilled additional dye penetrant testing should be used to test the hole perimeter for any cracks.

After the hole has been drilled, it could be left as-is or a bolt and nut can be inserted to plug the hole and help put the area around the hole in compression. Use of weld material to plug the hole, also referred to as a plug weld, is discouraged. These types of welds can cause additional cracks to develop in the base material, especially on vibrating steel bridge superstructures.

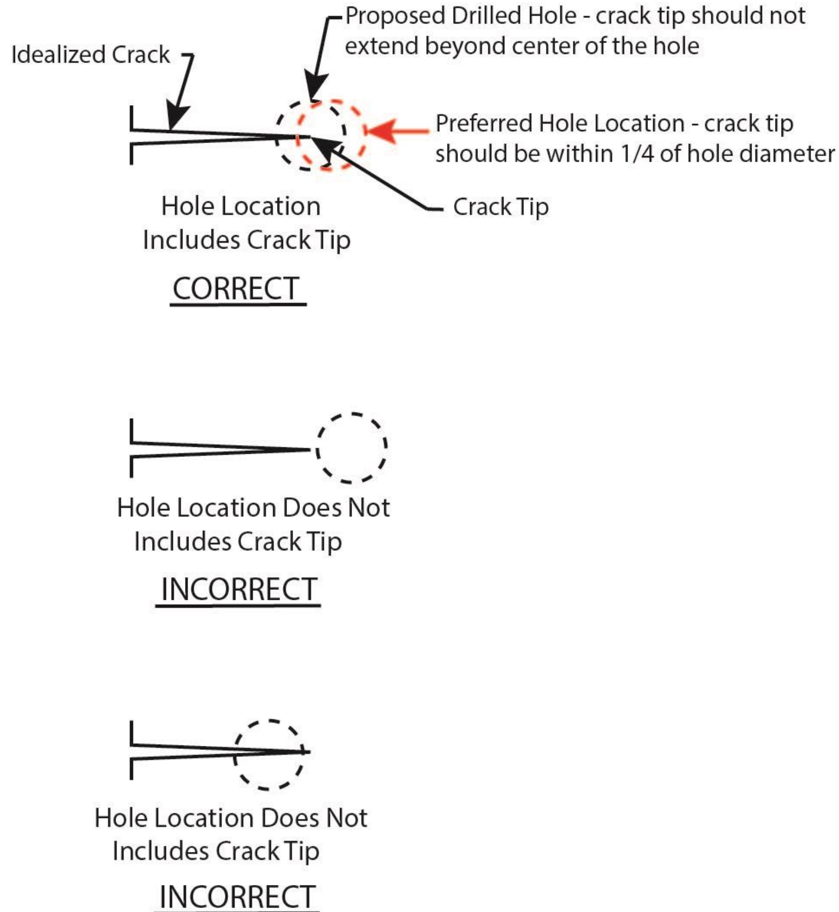


Figure 11.54 Drilled Arrest Hole Locations

11.5.3.3 StopCrackEX Technology

StopCrackEX Technology is used in military and aircraft industry to arrest fatigue cracks and more recently has been applied to bridge and building crack repairs. A cold-expanding bushing in the crack arrest hole creates a compressive field around the arrest hole. The additional compressive field created by the expanding bushing in the arrest hole further reduces the concentrated tensile stress field at the crack tip, mitigating crack growth. The StopCrackEX process is shown in Figure 11.55, where the gun is shown (left) and the resultant bushing and hole ahead of the crack tip is shown (right).

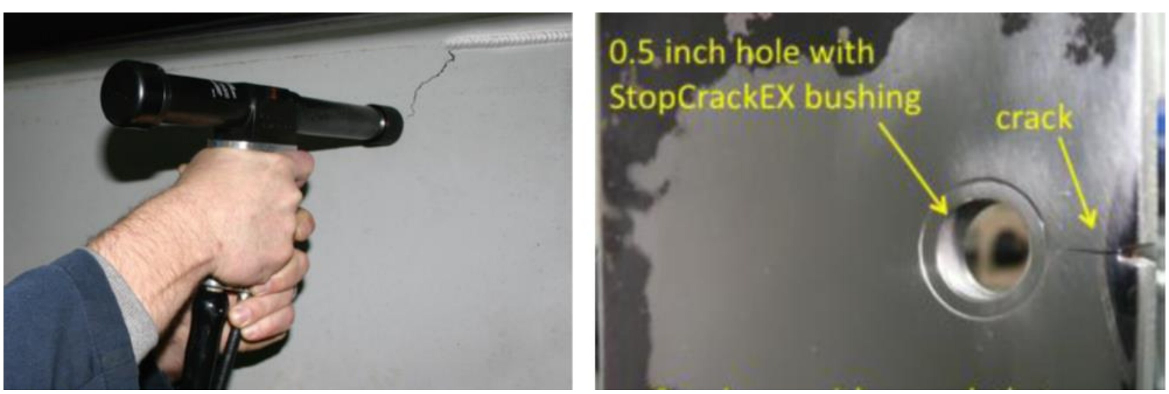


Figure 11.55 StopCrackEX Procedure

The StopCrackEx procedure utilizes the same approach as drilling the arrest holes, but requires smaller hole diameter (typically ½ inch) and is more effective due to the added benefit of localized pre-compression around the hole area.

11.5.3.4 Reinforcement Plate Strengthening

This repair provides strengthening by increasing the stress resisting area and reducing fatigue stress range stress. Strengthening or doubler plates can be installed on one side or both sides of the cracked member. Crack arrest hole should still be drilled at the toe of the crack and NDT testing is recommended prior to installation of the strengthening plate.

An example of an application for reinforcement plate repair is at a crack where a girder web has been coped. The photograph below, taken from the FHWA SHRP 2 Renewal Project R19A entitled “Design Guide for Bridges for Service Life”, is a good example of such repair.

Figure 11.56 Example of Reinforcement Plate Repair

11.5.4 Impact Damage

Physical impact damage due to over height or errant vehicles is common. Figure 11.57 shows an example of bridge fascia girder damage that was struck by a vehicle passing under the bridge. The bottom flange and web were bent out of plane from the impact. Additional examples of impact damage are shown in Figure 11.58 and Figure 11.59.

Figure 11.57 Bridge Fascia Girder Damage Caused by Under Passing Vehicle (Courtesy of the New York State Thruway Authority)

Figure 11.58 Impact Damage to Fascia and First Interior Girder (Courtesy of VDOT)

Figure 11.59 Impact Damage that can be Repaired with Heat Straightening (Courtesy of VDOT)

The damaged element should be inspected for fractures. The initial inspection can be performed visually and it should be followed by NDT testing, such as Magnetic-Particle Testing (MT) or Dye Penetrant Testing, to verify the extent of the damage. If fracture damage is present, the member should be repaired using splice plates, another engineered solution, or the steel member should be replaced in kind. If there is no fracture damage, heat or mechanical straightening repair can be used effectively. These techniques are discussed in 11.5.4.1 Heat Straightening and 11.5.4.2 Mechanical Straightening, respectively.

Small gouges can be removed by grinding with radius and flared back at 1:10 slope using the procedure provided in *The Bridge Maintenance Manual*, PennDOT Publication No. 55, 2002.

Suggested Procedure

Small Gouge Removal by Grinding (PennDOT manual)

1. Grind impact area to bright metal to remove any regularities and surface defects. Using a sanding disc, smooth area and round over edges. Finish grinding should be done parallel to the stress to ensure that transverse grind marks are not present.
2. If the impact is within the proximity of a welded detail, the weld toes should be smoothed with a die grinder to ensure that no microcracks were introduced during the impact. Using a sanding disc smooth the area and round over edges. Finish grinding should be done parallel to the stress to ensure that transverse grind marks are not present.
3. The impact should be flared back to the material edge at not less than 1 to 10 slope.
4. The area should be thoroughly inspected including any weld toes of details within the vicinity of the impact using the ultrasonic or magnetic particle testing appropriate for the detail.

11.5.4.1 Heat Straightening

Heat straightening is a well-known technique used to repair a deformed steel member. The method utilizes heating and cooling with a specific heating pattern and heating torch type.

Areas of steel superstructure members that have been damaged can be repaired by heat straightening alone or in combination with applying external force. Repairs designated for heat straightening should be properly engineered and detailed. In addition, a detailed step-by step repair procedure that includes heating pattern, acceptable cooling method, maximum heating temperature, temperature control, limits of heating length/areas, need for and magnitude of any external force, QC/QA procedures and other governing parameters should be developed.

Properly executed and successful heat strengthening can restore a damaged superstructure element to its original condition, geometry and capacity. The FHWA *Guide for Heat-Straightening of Damaged Steel Bridge Members* is a good reference for heat straightening repairs. An example of a heat straightening procedure is shown in Figure 11.60.

Figure 11.60 Example of Heat Straightening Procedure

When to Call the Engineer

Heat straightening should only be performed by experienced personnel under direction of an engineer with experience. Also temperature should be closely monitored to ensure steel is not overheated.

The photograph in Figure 11.61 shows a nearly completed girder repair that was made utilizing heat straightening. The heating pattern is clearly visible in the photo.

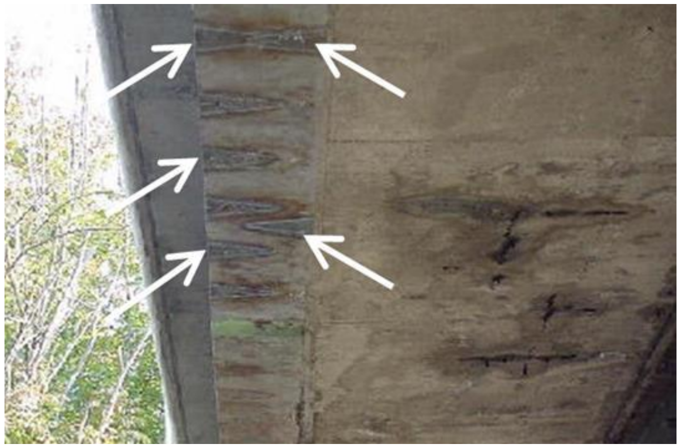


Figure 11.61 Nearly Completed Girder Repair Made Utilizing Heat Straightening (Courtesy of the New York State Thruway Authority)

11.5.4.2 Mechanical Straightening

Mechanical straightening, or cold bending, forces the deformed element into the original position by means of an external force. This is not a preferred method of repair, and it should be used on a limited basis for repair of minor and (most importantly) very localized damage. This type of repair has an increased risk of fracturing the damaged member when compared to heat straightening. Cold yielding also adversely affects mechanical properties of the base material. NDT testing (Magnetic Particle Test or Dye Penetrant Testing) of the repair should be done before and after mechanical straightening to verify that no cracks were created by the damage or the repair.

11.5.5 Tack Weld Removal

Tack or erection welds are widely used to temporarily hold connecting elements in place during construction. If not removed, they may develop fatigue cracks that could propagate into the base metal. Tack welds can be simply be removed by grinding followed by NDT testing. On completion of grinding, the area should be smooth, free of notches and any other surface defects that would potentially lead to development of a fatigue crack. The removal should not extend more than 1/16 inches into the base material without approval of the Engineer.

An example of a cracked tack weld that requires removal is shown in Figure 11.62.

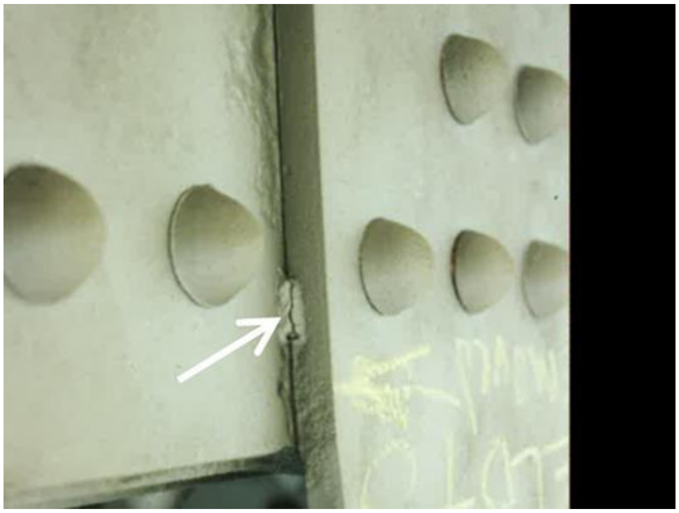


Figure 11.62 Cracked Tack Weld Requires Removal

11.6 Repair and Rehabilitation of Timber Superstructures

Repair and rehabilitation of timber structures involves one or more of the following activities; clamping and splicing new timbers to the existing structure, member repair or replacement, and/or employing external post-tensioning.

11.6.1 Clamping

Clamping involves the installation of steel plates above and below the timbers, which are drawn together by nuts and bolts or threaded rods depending on the depth of the timbers being clamped. The goal is strictly to prevent further splitting of the timbers. Clamping will not reverse the split by forcing the split back to its original pre-split position. A schematic of clamping was previously shown Figure 11.12 (top). Stitching, shown Figure 11.12 (bottom), involves the use of bolts or lag screws to contain the crack and prevent the timber from splitting further. The difference between clamping and stitching is that stitching can be done without interference with the surrounding structure; however clamping is a stronger mechanical bond and has shown better performance.

11.6.2 Splicing and Scabbing

Splicing and scabbing involves the addition of new material, usually either timber or steel, to allow a transfer of load through connections and around a cracked or split timber. Figure 11.63 (top) shows a typical spliced repair, in which two new timbers are installed on either side of the existing timber, and are sandwiched by either bolts or threaded rods with nuts. Typically, the spliced member should be cut all the way through to permit the splicing plates to properly assume the intended dead and live load carrying. This also ensures that each splice plate is equally handling its share of the load.

Scabbing, shown in Figure 11.63 bottom, is similar to splicing except that it often runs most of the length of the existing timber and is often only on one face of the existing timber. Scabbing is done more often since it allows a timber beam to carry a higher live load. Figure 11.64 shows a photo of a timber member repaired by scabbing.

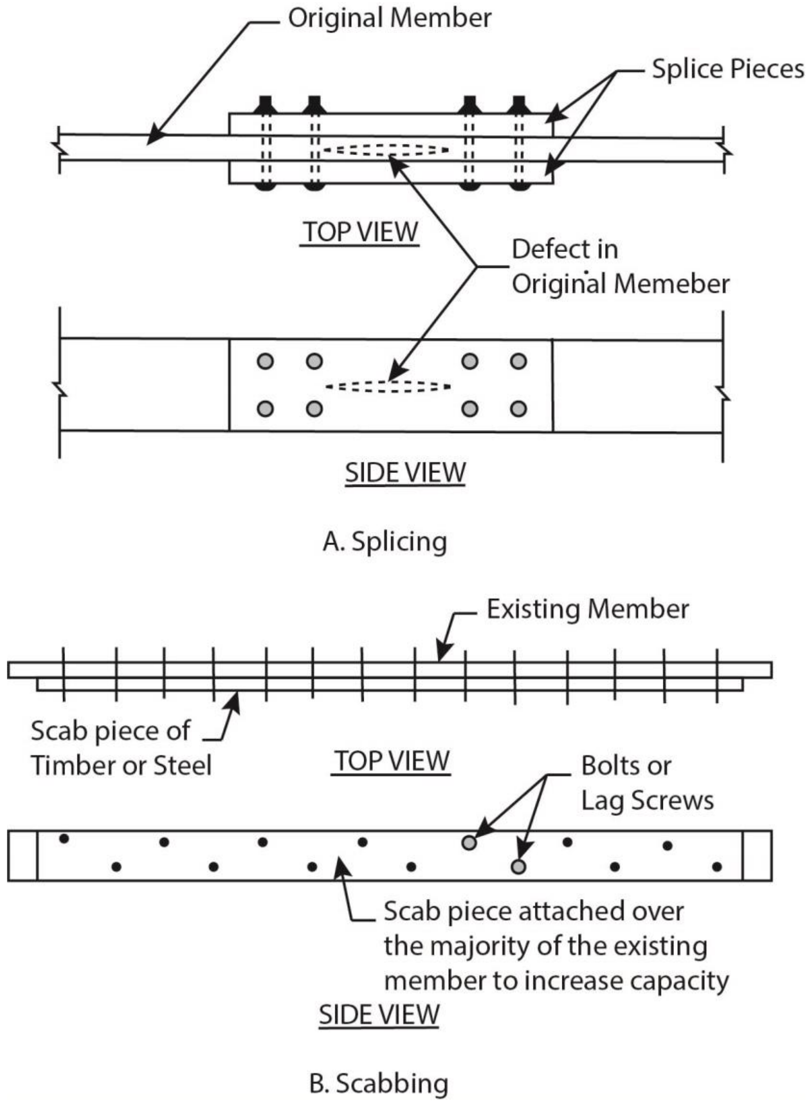


Figure 11.63 Splicing (top) and Scabbing (bottom)

Figure 11.64 Example of Scabbing an Existing Timber Member

11.6.3 External Post-Tensioning

Post-tensioning rods and cables have been used to strengthen or support existing timber members and to reduce or replace timber as truss members. These need to be checked during regular inspections.

Suggested Procedure

Post-Tensioned Rod and Cable Check

1. Note areas of corrosion and its severity. Significant section loss can lead to overstress due to higher tensile stress.
2. Check for broken members.
3. Pull or shake tensioning for looseness. If loose, cable tension has been lost.
4. Lightly tap rods and cables with a rubber mallet. Tensioned members will have a distinctive ring, non-tensioned members will not. Take care not to be struck by the rod or cable should it fail during the test.
5. Check anchorages for distress (cracks, strain, crushed wood).

In some cases, external post-tensioning is used to draw decks together similar to stress-laminating, but without the top surface being affected.

11.6.4 Repair of Timber Beams

Normally replacement is the most cost effective repair for decayed or damaged timber beams. A temporary repair can be made in some cases by turning beams with small damaged areas upside down, such as around the planking spikes. This may position the damaged area in a less stressed state, for example placing a damaged section in compression rather than tension. Often the repair will take as much time and effort as putting in a new beam and will result in a weakened beam with a short service life.

It is easier to replace a damaged beam if the deck is removed, but may not be practical if the deck is heavily spiked to all the beams, and only one beam is damaged. The usual practice is to install a new beam alongside the old beam, or one on each side. The new beam can be installed by cutting off one end of the beam at an angle so that it can be inserted into the space between the cap and the deck while clearing the opposite cap. After positioning the caps, the beam should be jacked up tightly against the deck, and hardwood or metal shims installed between the beams and the cap. The cut-off wedges from the angle cuts can be used as shims. The deck should then be spiked to the new beam. Figure 11.65 illustrates the replacement of timber beams.

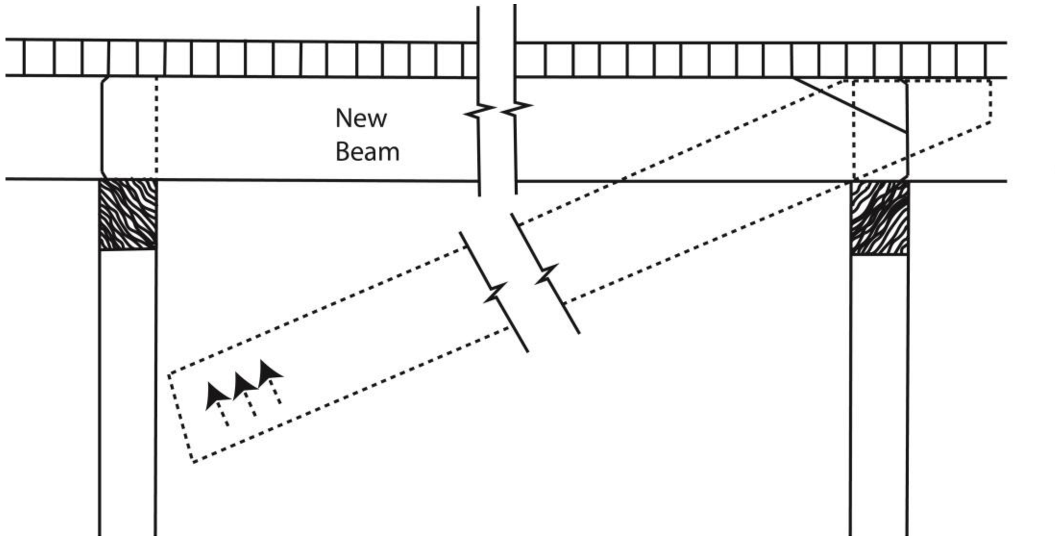


Figure 11.65 Timber Beam Replacement

Because of the difficulty in fitting a timber member of the same dimension into the available space, an alternative is to use a steel section that is smaller than the existing timber member, but has the same capacity or greater. Steel sections fit easily into the space and can be jacked into place. The sections can be rectangular shaped, round or any other shape that fits.

Suggested Procedure

Replacement of Timber Beam with Steel Support

1. A steel beam is installed between the bottom of the rectangular steel section and the top of the cap.
2. If needed, shims are tapped in between the top of the rectangular section and the deck for bearing.
3. Shims are tack welded into place.
4. For longevity, all steel members are hot dip galvanized ahead of time.
5. Welds or steel areas damaged during construction are sprayed with cold galvanizing paint.

For a photographic example of this type of replacement, please see Figure 11.66.

Figure 11.66 Rectangular Steel Section Replacement for Rotten Timber Girder (Courtesy of Washington DOT)

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