

PennDOT Truss Maintenance Manual



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Environmental Policy and Development Section



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1.0 Introduction

This manual provides guidance to state and local bridge owners on maintaining and rehabilitating metal truss bridges. The manual was developed as a part of the *Management Plan for Historic Metal Truss Bridges in the Commonwealth of Pennsylvania*. The purpose of the management plan was to develop an effective approach to manage the dwindling statewide population of metal truss bridges by balancing sound engineering with historic preservation considerations. There is wide spread interest in managing the state's dwindling population of metal truss bridges with proactive maintenance and by having rehabilitation or adaptive reuse considered as a routine part of the project development process.

Successful conservation strategies include routine maintenance activities that seem obvious but are regularly not performed due to competing staffing needs and limited budgets. There are effective and sometimes economical maintenance activities that, when performed regularly, can prolong the useful life of metal truss bridges.

Techniques to preserve, maintain, repair or rehabilitate metal truss bridges are presented using the framework of *The Secretary of Interior's Standards for Rehabilitation (1977, rev 1983, 1990)*. These standards provide guidance on maintaining and repairing historic resources while preserving the distinctive character of a resource but allowing reasonable change to meet new needs.

2.0 Components of a Metal Truss Bridge

A truss is a series of individual members, acting in tension (forces that pull outward) or compression (forces which push inward), forming a series of triangular shapes that transfer loads to the supports. There are three types of trusses (thru, pony and deck) and a variety of designs based on the arrangement of the series of triangular shapes. A **thru truss** is where the roadway passes between the truss lines and there is overhead bracing. Thru trusses are deeper and are used for span lengths greater than about 100'. The roadway also passes through the truss lines on a pony truss, but there is no overhead bracing. The **pony truss** is used for span lengths between 45' and 100'. The superstructure is above the roadway for both the thru and pony truss bridge. A **deck truss** has the superstructure below the roadway, and the flooring system is at the level of the upper chords, not the lower chords (Figure 1).

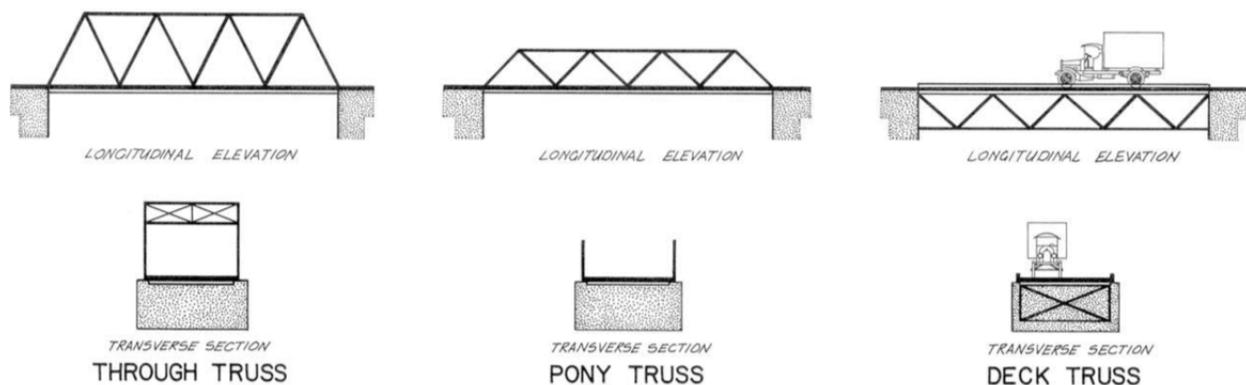


Figure 1 Types of Truss Bridges

The basic components of a truss bridge are presented in Figure 2. Many of the early truss bridges are pin connected. This means that the prefabricated members were connected together in the field at panel points by using

pins (cylinders with threaded ends secured with nuts) passing through the punched holes, pin plates or eyes. Although pin-connected truss bridges continued to be built into the 1920s in some regions, they had generally been eclipsed by riveted field connections starting in the 1900s. On rivet-connected truss bridges, members are connected to gusset plates at the panel points. There are two different techniques for making the end connections as shown in Figure 3. How the component members (chords, verticals, diagonals, end posts) are arranged defines the design, like Pratt, Warren, Parker, etc. It is important to know the type/design of all truss bridges and how the members are connected (Figure 4).

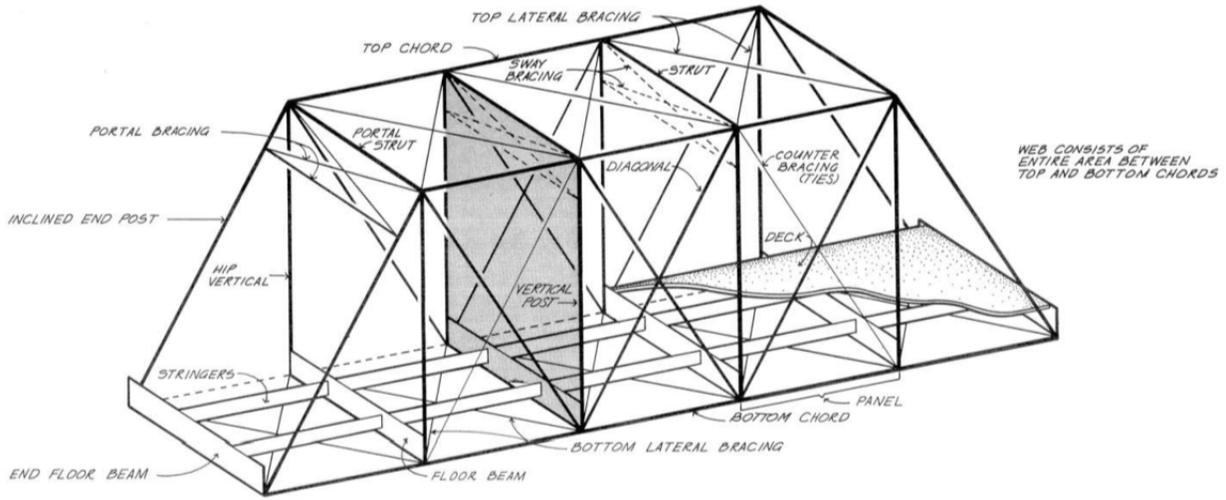


Figure 2 Basic Truss Components

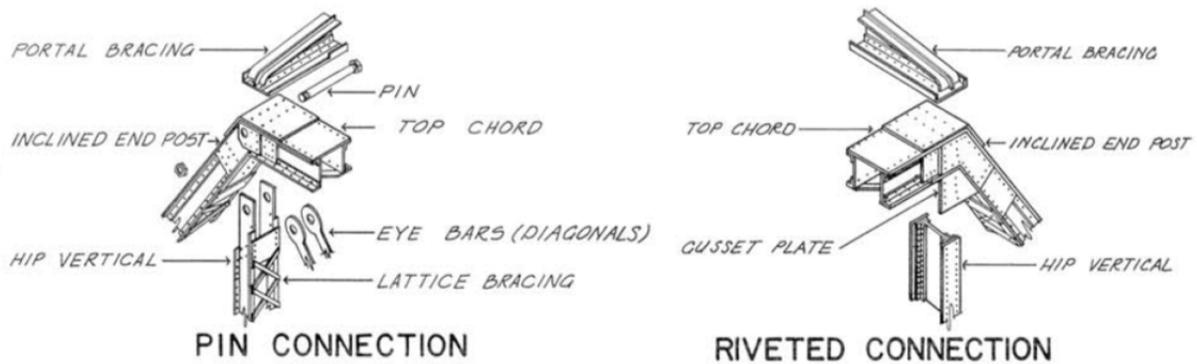


Figure 3 Structural Components

3.0 Preservation and Rehabilitation of Metal Truss Bridges

3.1 Maintenance and Preservation Treatments

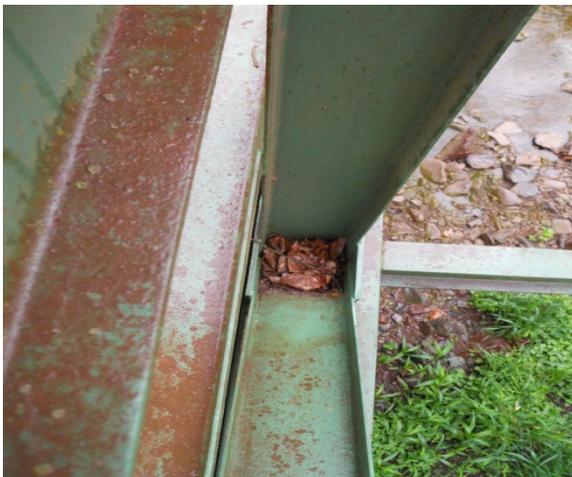
Clear Debris

The best maintenance and preservation strategy for preservation of steel truss bridges is to keep them painted and free from accumulated debris. This will minimize the effects that environmental factors and water have on the lifespan of the coating system, which when breached allows corrosion to form on the metal. Keeping the bridge as clean as possible will extend the life of the coating system as much as possible, which is important given the cost to re-coat and the inconveniences to the public that painting operations can have in the form of lane or bridge closures.

A principal source of moisture penetration and paint failure is debris, which frequently accumulates on exposed horizontal surfaces such as abutment seats at the bearings, top flanges of stringers, floorbeams and lower chord panel points. Rust can occur above and below the deck, and section loss due to corrosion can significantly reduce the load-carrying capacity of the truss. Rust also occurs at the interface of rivet- and bolt-connected members, a condition known as pack rust. Routinely removing accumulated debris and washing bridges with potable water when temperatures will be above frost or freezing levels will significantly lessen conditions that promote rust. A low-pressure washing should be performed annually. In locations where deicing salts are used, a wash each spring is recommended. (Refer to DM4 5.6.3 Bridge Preventive Maintenance, Section 56.31 Bridge Washing.)



Truss Bearing Covered with Dirt and Debris.



Typical Debris Accumulation at Lower Chord Joints.



Flood Debris on Lower Chord and Floor System.

Maintain Decks, Joints and Drains

Keep solid decks watertight by making sure that the joints/seals are intact, the drains are clear and the concrete is not cracked. This will prevent deck concrete spalls that may be caused by expansion of corroded internal reinforcing steel, as well as protect the beams and the substructure units from being subjected to any extra water or debris that could promote corrosion or allow moisture to be retained on the beams or pier caps. Deck cracks should be sealed and scuppers and bridge drainage systems should be cleaned and kept open. If not already in place, adequate means of draining water away from the bridge should be installed. Expansion joints should also be cleaned and kept in good repair or replaced as needed.



Large Area of Plated Over Concrete Deck Deterioration.



Underside of Bridge Showing Deterioration to Floor System due to Leakage through Bituminous Filled Pan Deck System.



Severe Stringer Deterioration at Abutment due to Leaking Deck Joint.

Maintain Coating System

The paint or coating system is the most significant mechanical tool for preservation of metal truss bridges, and also frequently the most costly. A sound coating system will prevent corrosion of the metal and require little additional work to the steel components. Paint/coating systems should be maintained. However, it is not necessary to rush out and spot paint every small area of corrosion as it appears. Maintenance and preservation activities related to paint and coatings should be done in a manner that is both cost effective and of maximum benefit to the overall operations. A more cost-effective method of maintaining the coating system may be to wait until several locations appear but before the corrosion has advanced to the stage that it is causing measurable loss to the steel. An option appropriate



Typical Bottom Chord Connection Detail.



Pack Rust with Section Loss at Lower Chord Pin.

for thru trusses is to only paint or coat the lower portions of the truss lines where debris accumulates and the potential for corrosion is the greatest. For a small bridge, moving the trusses to an offsite location for cleaning is often a cost-effective strategy, especially when combined with making other repairs.



100% Section Loss of Truss Vertical Web at Floorbeam Connection.



Pack Rust at Top Chord.

Wrought iron, cast iron and the various grades of steels used on bridges all require different levels of attention when considering painting. Wrought iron is not as prone to corrode, so it is not as urgent to paint areas where a coating may be peeling and exposing the metal. Research should be done to determine what the best coating system is for a given bridge. Consideration should also be given to what is the most cost effective way to clean and coat it as well as where that investment can be more beneficial. Some critical locations for painting are at the ends of the flooring system at expansion joints and truss lines at the bearings where the potential for corrosion is the greatest.

It is important to properly prepare the steel surfaces prior to painting. Preparing the metal surfaces of an existing bridge for application of a new coating system can easily account for half of the cost of a painting project. Applying

any coating to an improperly prepared surface is likely to result in poor adhesion and a much shorter lifespan for the coating. This will ultimately lead to more money being spent at the bridge to clean and re-coat the steel. Cleaning can be done to various degrees, but the best (and most expensive) method for getting a good coating system is to clean metal to a "white metal" condition. A less expensive method involves hand cleaning and power washing to a lower standard and applying a penetrating sealer that bonds any remaining paint and rust to the base metal, followed by one or two top coats of paint. This technique does not last long, but it costs considerably less.



Truss Relocated to Side While New Abutments Constructed. Note Paint Containment System.



Interior View of Containment System with Scaffolding for Access.

For older bridges, lead paint removal may be necessary, which will add to the cost due to requirements to provide greater levels of containment and personal protection for workers removing the existing coating. Lead paint removal can account for up to 75% of the cost of recoating. If it is unknown whether the existing paint contains lead or other toxic chemicals, the paint needs to be tested by an accredited laboratory as per DM4.



Containment and Vacuum System Required for Lead Based Paint Removal.

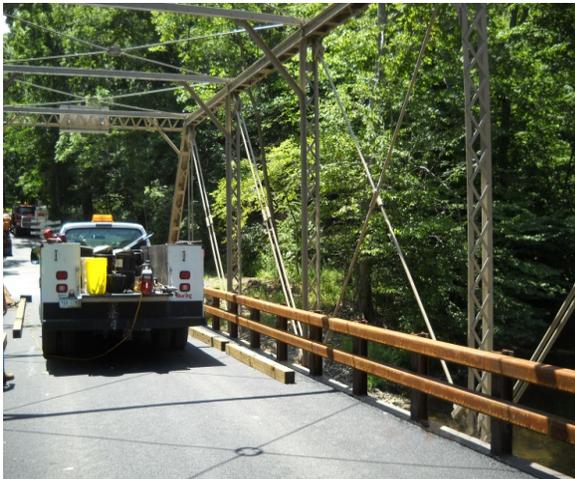
Protect the Bridge from Impact Damage

It is appropriate to install a traffic railing or beam guiderail system to protect the truss lines from impact damage. On one-lane bridges with adequate stopping sight distance, placement of guiderail also serves to clearly define to motorists that the bridge serves alternating traffic. Selecting traffic railing systems is an important conservation measure because it significantly reduces the chance that the bridge will be damaged or lost if a critical member is impacted/damaged.

All railing should be attached to the floor system, not the truss lines. As a result of the connection details, guide rail across the bridge is more expensive than guide rails on approaches. Whenever possible, any original railings should be left in place and modern, crash tested, traffic railings installed just inside the existing railings. Proper guide rail systems should also be in place at the approaches and should be continuous with the bridge railing.



Vehicular Impact Damage to Ornamental Bridge Railing.



Crashworthy Metal Bridge Railing.



Truss Vertical with Vehicular Impact Damage Prior to Guiderail Installation.

When aesthetic considerations are important, there are many standard and custom railing systems that can be used on historic truss bridges and their approaches, such as coated guide rail and wood-backed steel.

Replacement of Deteriorated Members

It is proper to replace deteriorated members in kind while maintaining the original pinned or riveted (bolted) connections. This is important to preserve not only for the appearance and historical significance of the bridge but also the way it performs. Pinned and rigid connection designs handle stresses differently. For example, replacing a failed eye bar on a pin connected bridge with a modern steel rod with end eyes that fit around the original pin is proper. This permits the bridge to continue to accommodate stresses as it was originally designed. Welding new or replacement members to a pin or welding the pin itself should be avoided as it creates a rigid connection that will

introduce forces for which the members were not originally designed. High residual stresses are then introduced, particularly into the tension members, and could lead to the initiation of cracks. Likewise, welding counters together to eliminate noise from vibration should not be done. Welding to the pins is seldom reversible. New material to replace deteriorated members can be higher strength or have slightly larger dimensions with no adverse effect.

There are many cost-effective approaches to increasing the load-carrying capacity of old bridges that do not have an adverse effect on what makes them historic. Generally accepted preservation guidance, including the National Park Service's *The Secretary of the Interior's Standards for Rehabilitation (1977, rev 1983,1990)*, allows for in-kind replacement of deteriorated fabric/members and adding new members, so there are a variety of successful methodologies ranging from replacing decks with lighter ones to post-tensioning longitudinal beams or tension truss members (post-tensioning may be utilized for short-term rehabilitations).

Truss members that have deteriorated or need to be strengthened can be replaced with higher strength steel equivalents as long as the connections are done in the original manner. Bolts are acceptable substitute for rivets and have been since the 1960s. It is also acceptable to use bolts to attach new material to existing members and to weld plates to existing cover plates, upper chords, end posts, and beam flanges in order to strengthen the bridge, if it is known for certain that the coverplate and beam are steel. Field welding, however, is generally discouraged due to lack of controlled environment. Reference is made to DM4 6.13.3.1 "Field Welding is generally prohibited. Provisions may be made for attachment of stay-in-place forms, bearing plates and sole plates of pot bearings (but not the pot bearing itself). All areas where field welding is permitted shall be specifically designated on the contract plans. The fatigue provisions of this specification shall apply to the design of all affected members. The regions of welded structures requiring non-destructive testing (NDT), along with the allowable types of NDT, shall be shown on the contract plans". If welding is performed, then a full understanding of fatigue design issues is an absolute must.

Bearings

Frozen expansion bearings on truss bridges are considered by many to be a non-critical deficiency. Most have been frozen for decades with little evidence of that causing distress. However, if it appears that the truss members are in distress due to thermal forces and the lack of ability to expand and contract, bearing replacement or modification should be considered. Bearings are rarely considered to be historically significant, so they can be replaced so long as the bearing function is maintained (i.e. fixed or expansion bearing).



Typical Expansion Bearing.



Rehabilitated Bearing with Rollers Removed and Replaced with a Neoprene Bearing Pad.

3.2 Rehabilitation Treatments

Deck Replacement

Replacing existing decks with lighter decks of concrete, timber, steel or other material is often an effective way to reduce dead load and thus increase load-carrying capacity. Decks and wearing surfaces are not historically significant features and changing them will generally not have an adverse effect. If significant overlay is present, consideration should be given to reduce its thickness. For bridges carrying railroad, ballast decks or ties are not historically significant features and can be replaced without an adverse effect. Before any decisions can be made about the extent of the replacement or repair of an existing deck, a deck condition survey should be conducted to determine if a partial or full deck replacement is required. Decks typically take the brunt of exposure to salts and debris. If a steel deck is used it should be galvanized. If a timber deck is used, it should be pressure treated. Refer to DM4 5.5.2.3 Decks. Concrete filled open grid steel decks are preferred over open steel decks. Open grid steel decks have a poor performance record. Fatigue cracking of welded grid members have been a continual maintenance problem, even on routes with low ADT.



Installation of FRP Deck System.

Floor System Upgrade

The flooring system is generally not a historically significant component. Fortunately, it is common for stringers to be weakest truss member and the floorbeams likely to be the next weakest, so that often the bridge load capacity can be improved by strengthening or replacing these members. It is very important that the floorbeams are connected in the original manner, meaning with eye heads or pin plates at pin connections or with bolts or rivets at gusset plates at rigid connections. Stringer-to-floorbeam connections are not as critical, which means that seat angles or notching does not necessarily need to be reproduced.

In-kind replacement of flooring system members with higher strength steel is an appropriate way to increase load-carrying capacity. In many instances, the floorbeams and stringers can be upgraded to increase load-carrying capacity by replacing the members in kind with modern steel that has higher strength.

Another way to increase capacity of floorbeams or indeed any beam is to weld or bolt cover plates to beam flanges. Bolting is preferred because field-placed welds commonly lack quality and can result in details that may be prone to fatigue-related cracking, particularly of concern for non-redundant members such as floorbeams. If welding is done at the bridge, care needs to be taken to never weld to the pinned or riveted connections of the truss. As discussed above, it is important to not change the original manner of connection at the panel point or gusset plate. (See welding note on page 9.)

Truss Member Strengthening

If the truss members do not have the capacity required, these are several methods available to strengthen them, including the addition of supplemental steel, providing auxiliary members and post-tensioning. These methods are discussed below.

Shapes built-up from angles (i.e., members like verticals, chords and end posts) lend themselves to being strengthened by using the conventional method of adding material to the flanges and webs. Adding section is a way to keep historic fabric in place, but it can also involve the removal of existing rivets and their subsequent replacement with high strength bolts. If the rivets are visually prominent and it is important to preserve the historic appearance and mechanical connection, button-head bolts can be used. It is important to define which side will have the head and which will have the shank. If not specified, the contractor will generally do whichever is easiest, not which is best for the appearance of the bridge. The same treatment can be used to replace or repair deteriorated sections of build-up members.



Addition of Auxiliary Members.

It is important to be aware of the type of metal of which the bridge is constructed. Most post-1895 truss bridges are steel, but the transition from wrought iron to steel starting in the mid 1880's was gradual. There are two low-cost, non-destructive tests that can be performed to characterize ferrous material as to whether it is wrought iron, mild steel, or steel. These include the spark test and field metallography where the metal is polished, etched and then its microstructure is replicated for examination in the laboratory. Iron and steel each have a distinctive microstructure that reveals which material it is.



Truss Replacement Member Connection Assembly.



Installed Assembly.

Steel members that by analysis have exceeded or will exceed their fatigue life within the expected life of the rehabilitation should be replaced in-kind. When fracture is a concern over the entire structure, consideration should

be given to providing auxiliary members or replacing the members in-kind. If cracks are found, the member should be replaced in-kind. The new auxiliary members should be positioned in the least conspicuous location. Typically, new upper chord members should be placed on the inside rather than the outside of the existing chords.

Any new auxiliary members need to structurally tie into the existing panel point connections. On pinned trusses, a new connection must be designed to connect at the existing pin. High strength bolts are appropriate for gusset plate connections on rigid connection trusses.

Post tensioning is a form of auxiliary member but is only useful to strengthen tension members of a truss. Post tensioning consists of installing a high strength cable or rod at both ends of individual members and tensioning the cable or rod to reduce some of the load carried by the members. The result is an increase in the live loads that the truss members can carry. Since the post tensioning principle relies on reducing the dead load capacity of the truss members, it is best suited for longer trusses where the dead load is very significant. This is a cost effective treatment that has also been used to provide redundancy.

Add Auxiliary Supports

When none of the above options are viable or the costs are prohibitive, placing auxiliary supports (also known as helper bents or underpinning) may be considered. Auxiliary supports for a truss bridge could be accomplished in several ways. One is to install steel stringers that span from abutment to abutment and support the live loads. The existing truss then support its own weight but does not carry live loads.

Another scheme is to place girders that span from abutment to abutment outside of the truss lines. The auxiliary girders are connected to the existing floor beams and share the applied loads with the existing trusses. Helper bents can be placed under the existing floor beams thus converting the bridge or span from simply supported to a continuous arrangement; however, this significantly changes the behavior of the truss.

Heat Straightening

Over the past decades, research has demonstrated that instead of mechanical force, which can further damage a member or impose residual stresses, heat straightening can be an efficient and economical way to repair steel members that have been deformed as a result of impact damage. The technique is to apply repetitive heating and cooling cycles and restraints to produce a gradual straightening of the material. Its advantages are that it is economical as it does not require removal of the member nor temporary shoring. The work should be performed by skilled professionals (there are several in the region) as the location and the amount of heat is critical to the success of the process. Additionally, extreme care needs to be exercised to remove nicks and other defects so there is no chance of future fatigue or fracture occurring. In 2000, FHWA issued *Heat-Straightening Repairs of Damaged Steel Bridges: A Technical Guide and Manual of Practice*. More in-depth discussion of the technique can be found in the recently completed NCHRP 10-63: *Heat Straightening Repair of Damaged Steel Bridge Girders: Fatigue and Fracture Performance*. This technique is most cost effective when several bridges in an area are repaired as a group as this spreads the mobilization cost over several bridges. The greatest expense is getting the practitioner to the site.

Increasing Vertical Clearance

Many thru truss bridges have a vertical clearance that does not meet current standards and/or requirements. Oversized loads that impact portal braces have the potential to dislodge sway bracing and vertical truss members.

When analysis supports that it is structurally acceptable to do so, the knee braces and lower struts of portal and lateral bracing can be raised or removed (as may be the case with knee braces at the portals) to increase vertical clearance across a bridge. This is a common technique to protect vulnerable members from impact damage, and it generally has no adverse effect on the bridge. Since this issue is not new, it is quite possible that the lower struts and knee braces have already been raised or are an in-kind replacement of the original fabric. Any raising of members, however, needs to be kept in scale with the overall proportions of the bridge, which means that less increase is possible on shorter and smaller spans than on longer and larger ones.



Substandard Vertical Clearance with Portals and Bracing Existing Collision Damage.



Modified Portal and Sway Bracing System Modified.

Enforcing vertical clearance can be achieved by erecting barriers that restrict passage of vehicles that conform to posted height limit. This strategy also serves the purpose of limiting overweight vehicles.

Increase Horizontal Clearance

Both pony and thru truss bridges have been widened successfully, and the treatment is popular with the public but it is recommended only when none of the other treatments can provide the desired operational and functional criteria. Whether or not a truss bridge is a candidate for widening will depend on, among other issues, its length and how much it needs to be widened. Proportionally a 70'-long and 18'-wide pony truss bridge usually cannot accommodate a 10' or 12' widening, but a 140'-long and 18'-wide thru truss might. (Note – dimensions provided for comparison only and do not represent engineered values.)

Widening is accomplished by removing and then cutting the truss lines inside the lower panel points taking care to retain a truncated section of the floor beam and then moving the truss lines out and installing a new superstructure such as steel stringers or prestressed box beams. Typically the truncated floor beam ends are connected to the fascia beams, and the trusses support only themselves and any sidewalks. Any portal upper bracing is extended in kind or replaced in kind to match the width (see Figure 5).

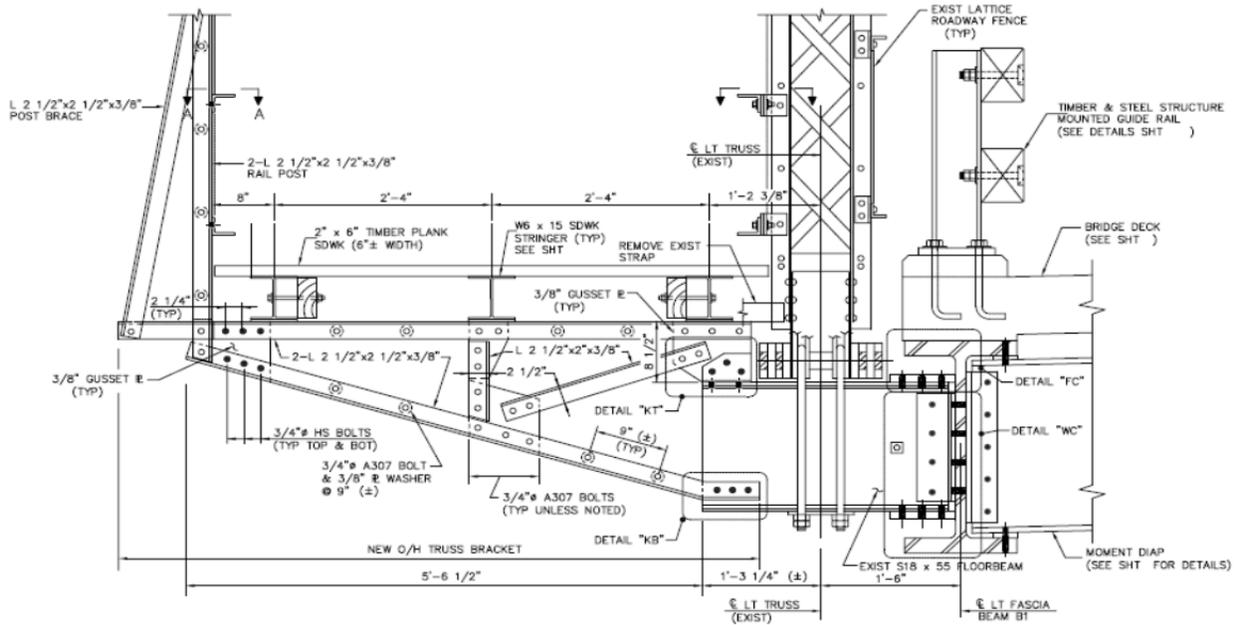


Figure 5.

If a truss bridge does not need to be widened very much, and if supported by analysis, it may be possible to install a new, wider flooring system with longer floor beams instead of a new superstructure. Care needs to be taken to ensure that the new flooring system is connected at the lower panel points in the historic manner.

In both widening schemes, the substructure units will have to be extended. Substructure units are generally not historically significant and their extension with concrete units faced with masonry or finished with form liners would be appropriate. While this strategy has been evaluated in the past to have an adverse effect on historic truss bridges because the original proportion of the bridge is changed along with the superstructure, it has become increasingly



Salvaged Truss Line Ready for Attachment to Fascia Stringer.



Truss Line Attached to Fascia Stringer.

popular with the public and preservationists. Truss bridges are often character-defining resources and their presence in the landscape, as well as the record of important bridge type, is highly valued.

3.3 Adaptive Reuse

In many instances, the geometric deficiencies are so significant that the truss bridge, which is often narrow and located on sharp curves, cannot remain in service. When it is not possible to keep the bridge in service, it is appropriate to remove it and relocate for adaptive reuse. Since the advent of metal truss bridges into the middle of the 19th century, they have historically been dismantled and relocated, so doing so continues a historical trend. Nineteenth century truss bridges, in particular, are important artifacts that merit placement in a more restricted use setting, like on pedestrian and bicycle trails or in parks. Moving a historic truss bridge and rehabilitating it for an adaptive use is an acceptable treatment, and the relocation is often considered as the mitigation of any adverse effect the removal of a historic bridge may have. It is a treatment that does result in the preservation of the historic bridge. There are many truss bridges that have been preserved for adaptive use on trails, parks or other recreational uses.

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