

A New Look at Modern Timber Bridges

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Abstract

Bridge owners often view timber bridges with suspicion. Can a timber bridge carry the required highway design loading? Will a timber bridge last 75 years? Are there crash-tested rail systems available? Can a durable wear surface be installed on a timber deck? Is the preservative treatment environmentally safe? These are some of the concerns raised when considering a timber bridge option. The timber industry has addressed each of these concerns and today's timber bridges are performing exceptionally well. This paper discusses each of these items and explains how Modern Timber Bridges meet and exceed the expectations of today's bridge owners.

Introduction

In planning for a new bridge, owners and designers must put several puzzle pieces together to see the complete picture. These pieces include expected service life, span length, economics, loading requirements, serviceability, aesthetics and others. With all of these criteria considered, the owner and designer will desire to choose the bridge material that best meets all of the requirements. Advances in timber bridge technology over the last several decades have improved timber bridge performance to make them competitive with more common bridge materials. This paper will examine each piece of the puzzle in choosing a bridge material and explain how timber bridges meet the requirements for many bridge applications.

I. Longevity

In recent years owners such as state departments of transportation have begun to require a service life of at least 75 years for bridges. In order to achieve a life span of 75 years a bridge needs to be constructed appropriately. Preservative treatment of the wood members provides the first line of defense against deterioration caused by fungal and insect attacks. The AASHTO LRFD Bridge Design Specification (AASHTO, 2010) states that, "oil borne preservatives have proven to provide adequate protection against wood attacking organisms. In addition, the oil provides a water repellent coating that reduces surface effects caused by cyclic moisture conditions."

Most issues relating to longevity of timber bridges deal with allowing decay organisms access to untreated wood. For example, before cast aluminum deck clips became available, deck panels were often attached to the longitudinal girders with drive spikes. The spike penetrated the treatment envelope and permitted moisture to reach the untreated portion of the wood. Another common scenario occurred when the timber material was fabricated on site, after the treatment process. Again the treatment envelope was violated and moisture was able to penetrate into the untreated wood.

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When unseasoned wood is used to build bridges the seasoning process can lead to checking of the members. While seasoning checks typically do not affect the strength of the member, they can extend beyond the treatment envelope and permit moisture to reach untreated wood.

When moisture is permitted to reach untreated wood, the moisture content can reach a level where decay fungus can propagate, resulting in decayed members and a shortened life span.

To avoid penetrating the treatment envelope, methods were developed to completely detail all of the bridge components, allowing the members to be completely fabricated before the members are pressure treated. Holes for beam seats, diaphragms, post and curb attachments are now drilled in a fabrication facility. Aluminum deck clips are now used to connect the deck panels to the longitudinal stringers. These clips grip a pre-routed slot in the girders without penetrating the treatment envelope. See Photo 1. Note that the timber girders were prefabricated for bolt holes at post braces and diaphragms. The deck and posts were prefabricated for the post brackets. This bridge was then preservative-treated with pentachlorophenol in heavy oil. Using these methods, moisture is prevented from reaching untreated wood and decay organisms cannot attack the wood.



Photo 1. Timber Bridge with aluminum deck clips.

Several recent assessments have shown that properly detailed, fabricated and treated timber bridges remain in excellent condition for up to 75 years. (Wacker et al. 2014)

A notable example of a long lasting timber bridge is the Keystone Wye bridge on an interchange on US Highway 16 in South Dakota, near Mount Rushmore. This bridge was completed in 1968. Recent inspections have determined that this bridge is performing exceptionally well and will continue to do so for many years to come.



II. Strength

A common misperception is that timber bridges are viable only for low volume, low speed rural roads. While the strength of a timber bridge can be limited by the use of sawn timbers, the use of glued laminated wood members greatly increases the potential carrying capacity of these bridges. Glued laminated members (glulam) are manufactured in such a way as to increase the strength of the members. For example, the allowable bending stress of a Douglas Fir Select Structural beam is 11.0MPa (1600 psi.) Stringer sizes greater than 60.96 cm. (24 in.) deep are difficult to procure which also limits the available strength of sawn members.

With glued laminated members it is possible to achieve bending stresses of 16.54MPa (2400 psi). Glulam members are made by end jointing individual boards into a

continuous lamination and then building these laminations into a beam. With these procedures it is possible to manufacture beams up to 228.6 cm. (90 in.) deep.

In the Tongass National Forest in SE Alaska, close to 90 timber bridges were built in the 1980s that were designed to carry off-highway logging trucks and log loaders. These trucks had a Gross Vehicle Weight (GVW) of 92.53 metric tons (102 imperial tons) with a wheel base of 19.35m (63'-6"). The maximum axle load for these trucks was 249.09 kN (56,000 lbs.) These trucks are almost twice as heavy and 3.66m (12'-0") shorter than the 469.26 kN (105,500 lb.) GVW trucks permitted in Oregon. The log loaders had a GVW of 400.32 kN (90 imperial tons) with a 4.57m (15'-0") track length which produces greater stresses in the stringers than the 92.53 metric ton trucks. Clearly, properly designed timber bridges are capable carrying today's highway loads.

III. Span Length

It has become increasingly difficult to obtain permits to construct bridge abutments or intermediate piers in flood plains or riparian zones. Many bridge specifiers have found it much simpler to keep all bridge foundations out of the waterway altogether.

People are often surprised when they learn that timber bridges can span more than 10m or 12m. (~30 or 40 feet.) Again with glulam technology, it is possible to manufacture longitudinal stringers up to 41.14m. (135'-0").

Truss Bridges and arch bridges are options for longer spans. Timber arch bridges can be designed to span 60m (~200'-0") and timber truss bridges can reach 90m (~300'-0") without interior supports. Figure 2 is a 42.67m (140'-0") tied arch bridge in Teaneck, New Jersey and Figure 3 is a 85.34m (280'-0") camelback truss bridge over the Placer River in Alaska. The foundations of this bridge were located in such a manner as to keep the bridge superstructure above the expected ice flows from Spencer Glacier located just upstream. This bridge is designed to carry a 6.04 kN/m² (126 psf) snow load which is roughly equivalent to HL-93 loading.



Photo 2. Overpeck Park Bridges in Teaneck, New Jersey are designed to carry two lanes of traffic with HS25 loading.

IV. Rail Systems

As recently as the 2002 the AASHTO Standard Specifications for Highway Bridges contained provisions for the design of bridge railings. These included requirements for strength and limits on the height of openings. The rails were designed to resist a 10,000 lb. lateral load using elastic design criteria. Tests run on commonly used rail systems resulted in failures and demonstrated that the static design load was not sufficient to ensure adequate rail performance. In 1989 the Federal Highway Administration mandated that all bridge railings used on the National Highway System meet crash-tested design requirements. (AASHTO 1996)

A crash-tested rail system is a railing system that has successfully completed a series of vehicle impact tests as specified in the National Cooperative Highway Research Program report 350. (NCHRP 1993) This report includes a matrix specifying the mass of a vehicle, the speed and the angle of impact for six levels of railings, Test Level 1 through Test Level 6 (TL1-TL6). Successful completion includes three primary criteria, structural adequacy, occupant safety and after-collision vehicle trajectory. This is a significant change in bridge railing requirements.



Photo 3. The Whistle Stop Bridge in Portage Alaska
(Photo courtesy of Eleanor Oman, US Forest Service)

The US Forest Products Laboratory took a very proactive approach to this change in requirements and completed crash testing for longitudinal deck bridges (or slab bridges) and longitudinal stringer/transverse deck bridges for both TL-2 and TL-4 test levels. TL-2 railings are acceptable for most local and collector roads with favorable site conditions, as well as where a small number of heavy vehicles are expected and posted speeds are reduced. TL-4 systems are acceptable for the majority of applications on high-speed highways, freeways, expressways, and interstate highways with a mixture of trucks and heavy vehicles. Basically, a crash-tested system is available for any site where a timber bridge is considered. (Faller et al. 1999)

V. Wear Surfaces

Because timber bridges are constructed differently than steel or concrete bridges, material-appropriate designs and methods needed to be developed to allow the proper application of asphalt wear surfaces on timber decks. The Forest Service has developed extensive guidelines for asphalt pavements applied to timber decks. (Eriksson, et al. 2003) These guidelines include limiting deck deflections to 1.27mm (0.05 inches), utilizing deck stiffeners to limit inter-panel deflections, specifying asphalt mixes compatible with treated timber, minimizing preservative treatment residue on the deck surface, and applying a paving membrane on top of a base layer of asphalt. See photo 5. Using these guidelines, the asphalt wear surfaces can be applied that show no signs of reflective cracking.



Photo 4. A timber longitudinal deck bridge with a TL-2 rail without a curb.

VI. Environmental Considerations

Beginning with the introduction of the document, “Best Management Practices for the Use of Treated Wood in Aquatic Environments” or BMPs (WWPI 1996), the preservative treating industry has made significant improvements to the way treated wood is provided when used in and near sensitive environments. By requiring conformance to these BMPs the bridge specifier minimizes the potential for adverse impacts on the environment.

The BMP criteria provides the following six criteria for performance.

- 1) **Chemical Minimization.** Only the minimum amount of preservative required to provide protection against insect and fungus attack is used in the wood members.
- 2) **Product Cleanliness.** Processes such as expansion baths or steaming are used after the preservative cycle to make certain the surfaces of the wood are clean and dry.
- 3) **Inspection and Rejection.** Each charge of treated wood is inspected for product cleanliness. Charges failing this requirement are returned to the pressure cylinder for additional cleaning processes.
- 4) **Fixation.** The treated wood is kept on a drip pad until the preservative chemicals have completely fixated to the wood cells and have stopped dripping.

- 5) Field installation guidelines are included to minimize contamination of the site during field treating of holes, cuts or injuries which occur after the product is delivered to the site.
- 6) BMP Quality Control and Certification. A quality control program has been developed to certify products that have been treated in conformance to the BMPs. The BMP quality mark is placed only on those products that conform to the BMPs. Certificates of conformance are also available.



Photo 5. Paving operations on the Overpeck Park Bridges

Significant research has been done in the last 15 years to assess the environmental effects associated with treated timber bridges in aquatic environments. These studies looked at the environmental effects of treated wood bridges in sensitive environments. The studies examined the water column and sediments under bridges and boardwalks treated with a variety of common chemical treatments. The bridge sites that were chosen represented “worst case projects with respect to preservative contamination of the water column and sediments.” These studies found that preservatively treated timber bridges present little environmental risk. (Forest Products Laboratory, 2000; Brooks, Kenneth M, 2000.)

In 2011 the Forest Products Society published, “Managing Treated Wood in Aquatic Environments.” (Morrell et al. 2011) This document contains a wealth of information

regarding preservative treatments and their impacts on the environment. Additionally, an environmental model is introduced that predicts the concentration of preservative chemicals in the water column and sediments near a bridge based on the size of the bridge, the flow rate and the PH of the water column. Using this tool, agencies can assess the impacts of treated bridges and specify measures to mitigate the impacts if it is concluded that the presence of the treated wood poses an unacceptable threat to the environment.

VII. Economics

Economics is one of the key considerations in choosing a bridge material. Timber bridges have several characteristics that make them competitive with other bridge materials. In the right locations, timber bridges are often the least expensive option for bridge construction. For example in the Tongass National Forest in SE Alaska, dozens of bridge contracts were let based on a bidder design specification that allowed treated timber or steel construction. Over 90 timber bridges have been procured in this manner. Photo 6 shows the construction of a 36.88m (121'-0") bridge on Prince of Wales Island in Alaska. Prefabricated timber bridges are easily installed and do not require highly skilled labor to erect them. Timber members weigh significantly less than steel or concrete members. This affects freight charges, abutment design and costs of lifting equipment. The construction time for timber bridges can be significantly less than a comparable steel or concrete bridge.

VIII. Aesthetics

The AASHTO LRFD Bridge Design Specification states that, "bridges should complement their surroundings, be graceful in form and present an appearance of adequate strength." (AASHTO, 2010) This criterion is easily achieved with the use of timber bridges, especially in rural and natural settings. Treated wood blends into natural sites in ways that other bridges cannot. For example, The Oregon Department of Transportation and the US Bureau of Land Management chose a timber bridge to provide access to hiking trails on a high profile project in southern Oregon. The Tioga Bridge in southwest Oregon fits beautifully in its location spanning the North Umpqua River (Photo 7.)

IX. Sustainability

With the national emphasis on sustainability and green building in the construction industry it will be only a matter of time before these criteria begin to be a significant factor in the choice of bridge materials. When it comes to sustainability and environmental impacts, wood is the clear leader over all other building materials. Wood is the only renewable building material. As a matter of fact, the US grows 27% more wood fiber than is harvested each year. Oregon, for example, enacted the Forest Practices Act in 1971 requiring replanting of forests within two years of harvest, maintaining buffer zones around rivers and creeks, and protection for wildlife and fisheries.



Photo 6. Alaska Logging Bridge using backhoes for installation.
(Photo Courtesy of Eleanor Oman, US Forest Service)

Based on a life cycle assessment of similar structures made with either wood, steel or concrete, wood building materials have 17% less embodied energy than steel and 16% less embodied energy than concrete. Wood building materials release 14% less air pollution than steel and 23% less air pollution than concrete, emit 26% less greenhouse gases than steel and 31% less greenhouse gases than concrete. Wood building materials discharge a quarter of the amount of water pollution as steel, and a third of the amount of water pollution as concrete over the life of the structures. (Lipke, 1997) From an environmental standpoint, timber bridges leave a much lighter footprint on the environment than other bridge materials.



Photo 7. Tioga Bridge over the North Umpqua River

X. Summary

The timber bridge industry in the United States has worked diligently over the past two decades to put all of the puzzle pieces together to provide the complete picture for the use of treated timber as a bridge material. The individual puzzle pieces are:

- Improvements in design, detailing and fabrication have been made that result in bridges with a 75 year life expectancy.
- Use of glulam stringers, decks, and other structural members allow timber bridges to be designed to carry today's highway loads with spans up to 300 feet or more.
- Development of crash tested rail systems to meet FHWA requirements.
- Recommendations for the design and installation of durable wear surfaces.
- Best Management Practices for the Use of Treated Wood in Aquatic Environments.
- Environmental modeling to assess the effects of a timber bridge on the water columns and sediments.

In addition to these advances, timber bridges have inherent properties that enhance their position when considering a bridge material. Timber bridges are cost competitive in many bridge projects, especially where the lightweight nature of the wood provides for less expensive abutments and lifting equipment. Timber bridges are naturally beautiful, come from a sustainable, renewable resource and have a smaller impact on the environment than other bridge materials.

Clearly, timber bridges meet all of today's criteria for bridge construction. Timber bridges should, therefore, be strongly considered when selecting a bridge material.

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