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CHAPTER SIXTY-FIVE

WOOD SUPERSTRUCTURES

The AASHTO *LRFD Bridge Design Specifications*, Section 8, describes criteria for the design of a wood superstructure. Requirements for the design of wood decks and deck systems are described in the *LRFD Specifications*, Article 9.9. A useful reference book, *Timber Bridges, Design, Construction, Inspection and Maintenance*, is listed at the end of Sections 8 and 9. This Chapter describes general guidance in the design of a wood superstructure. The Chapter is structured as follows:

1. Section 65-1.0 provides general information for which there is not a direct reference in *LRFD Specifications* Sections 8 or 9.

2. Sections 65-2.0 and 65-3.0 provide information which augments and clarifies *LRFD Specifications* Sections 8 and 9. To assist in using these Sections, references to the *Specifications* are provided herein immediately following section titles, where applicable.

See Section 59-3.0 for additional information on wood superstructures.

65-1.0 GENERAL

65-1.01 Background

Most of the first highway bridges constructed were made from native untreated wood and were subject to insect and decay damage. Decay fungi have the basic requirements for growth and production of decay in wood, as follows:

1. air (they are aerobic organisms);
2. water;
3. a favorable temperature; and
4. a food source.

Wood can be protected by the elimination of just one of these favorable conditions. The food, of course, is the wood itself. This food may be made unavailable to the fungus by impregnating substances into the wood, making it unpalatable to attack organisms. Pressure treatment with approved wood preservatives is the only acceptable and effective method of wood preservation. The fire potential of wood superstructures can be substantially reduced by better design choices,

such as by using bridge members and components that have low surface-to-volume ratio. This can be done by using large solid sawn members and by laminating individual wood members into large components, such as beams and panels.

There are a number of different species of both softwoods and hardwoods that can be used for bridge construction. The choice of species is influenced by several considerations. For example, the availability of the cross-sectional sizes and lengths necessary for the actual structure is a consideration. The sizes used for highway bridges available in hardwoods are severely limited.

The availability of large, long members is considerably greater in western softwoods, especially Douglas fir-larch. A more important issue, from an engineering standpoint, is not necessarily availability, but rather certified grading and material certification. Most softwood production comes from mills that have a certified grading system in-place, whereas much of the hardwood production comes from mills that normally grade production based on appearance and not on strength.

Also, with respect to the choice of species, most of the commercially-available softwood stress grades can be readily treated with wood preservative to current specifications. The one softwood species that cannot be adequately treated is spruce. Hardwoods, in contrast, do not have a long historical record of treatment and performance for many of the species and wood preservatives.

Wood as a bridge construction material offers some advantages over steel and concrete. It responds well to impact loading and, unlike crystalline material, it fatigues at a very low rate, so low that fatigue considerations are not included in the design process. Treated wood is immune to the destructive actions of deicing chemicals. Treated wood is unaffected by freeze-thaw cycles.

Some disadvantages to the use of a wood superstructure are that it can burn and is generally not suitable for long spans. Many wood preservatives may be harmful to the environment; and the preservatives may not prevent long-term decay of the wood. A wood deck is generally not suitable for a high-traffic volume road due to spalling, cracking, or delamination of the asphalt wearing surface.

65-1.02 Usage

A wood superstructure should be limited to a low-volume, local road. Its use is subject to the approval of the Production Management Division's Office of Structural Services manager. A request to utilize a wood structure should address the items as follows:

1. cost;
2. AADT;

3. ADTT;
4. bridge-railing requirements;
5. local experience with wood structures; and
6. local maintenance capabilities.

A wood bridge, because of its rustic appearance, is very appropriate for use in a park, environmentally-sensitive location, or recreational-area project. A treated wood bridge may be used for a short-span locally-funded project, or for a trail or temporary structure. Structural components made of wood may be used on a rehabilitation project, wood-covered bridge, or a deck system for use on a steel truss. Figure 59-3B shows the approximate span-length range for the different types of treated wood structures.

There are practical considerations that are unique to wood structures that should be followed in the ultimate location and configuration of a wood structure. In addition to the transverse crown, it is advisable to have a profile grade of at least 0.3% to ensure complete deck drainage. The profile grade in the deck can be provided by means of a vertical curve. Longitudinal timber deck panels cannot be cambered to offset dead-load deflection. One of the recognized hazards of a timber bridge is fire. The potential for fire damage can be reduced by the use of large members and components with a low surface-to-volume ratio. A design features that will reduce fire potential is the proper placement of riprap. Properly placed riprap, in addition to providing protection from erosion, prevents the growth and accumulation of combustibles around the wingwalls and abutments.

Each wood superstructure should have a minimum of 6 in. freeboard above the design high water elevation based on the Q_{100} discharge.

65-1.03 Wood Bridge Railings

Bridge railings for a wood structure should be in accordance with the Test Level selection requirements provided in Section 61-6.01(01). There are no INDOT *Standard Drawings* for bridge railings that can be used on a wood structure. However, a useful reference regarding crash-tested wood bridge railings is a CD-ROM entitled *The National Wood in Transportation Program, Information on Modern Timber Bridges in the United States, 1988-2001*.

Where roadside barriers are installed at bridge railing ends, the barriers should blend in naturally with the surrounding environment, e.g., wood rails on wood posts.

65-2.0 BASIC CRITERIA

65-2.01 Materials

Reference: Article 8.4.1

The AASHTO *LRFD Specifications* provide design information on most of the commonly-used species and stress grades of wood-based products for a treated wood structure. A more complete listing may be found in the American Wood Council of the American Forest and Paper Association's *LRFD Load and Resistance Factor Design Manual for Engineered Wood Construction*. That publication includes references to *AF&PA / ASCE 16-95, Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood Construction*.

The extensive listing of a specific stress grade in either of the above-referenced sources does not imply that all of the listed stress grades are commercially available in the sizes and lengths required in bridge construction. The designer should check with regular suppliers of wood components for availability and cost in the final selection of size and stress grade of major bridge components.

65-2.02 Preservative Treatment

Reference: Article 8.4.3

All wood components used at a site conducive to decay and insect damage, such as a highway bridge, should be preservative-treated. Surfaces which are expected to be touched often by humans, e.g., pedestrian railings, should be treated with waterborne preservatives. All other components should be treated with oil-borne preservatives.

Details should be developed to show where all of the possible cutting and drilling will be done prior to pressure treatment. A spike or nail can provide access to the untreated interior portion of the wood component.

65-2.03 Metal Components

Reference: Article 8.4.2

The *LRFD Specifications* describe the design requirements for metal parts and attachments to a wood structure and their respective source specifications. Metal components employing forms of corrosion protection, such as weathering steel, epoxy coating, or cadmium plating, can be used where determined by the designer to be appropriate for the intended exposure condition.

Light-gage toothed metal connector plates are permitted by *LRFD Specifications* Article 8.4.2.2.8, but they should not be used in the superstructure as they tend to pull out under repetitive loading.

The design of structural-steel components should be in accordance with *LRFD Specifications*, Section 6.

65-3.0 DESIGN

65-3.01 General

Reference: Article 8.4.4

Considering strength versus weight, wood is a very efficient structural material. For example, an ultimate tensile strength of 13 ksi is obtained in testing straight-grained British Columbia fir. The same wood provides an ultimate compressive strength of approximately 11 ksi, indicating a slight compressive cellular instability of the material under compression parallel to grain. Because of the presence of knots, slope of grain, splits and checks, and other discontinuities, only a fraction of straight-grain specimen strength can be used in actual design.

Lumber grading is the process of separating lumber at the mill into categories that have the same strength-reducing characteristics or, groups that have the same strength properties. The size, extent, and combination of strength-reducing characteristics permitted within a specific stress grade are formalized and are then published in the form of Grading Rules. Grading Rules unique to each species or combination of species are approved by the Board of Review of the American Lumber Standards Committee and certified for conformance with U.S. Department of Commerce Voluntary Product Standard PS 20-94 (American Softwood Lumber Standard).

The primary purpose of lumber grading is to ensure that populations of wood products specified as being a specific stress grade will all exhibit material properties that are consistent with the published values for that specific stress grade. The process of grading takes place at the point of production of the product. The only method presently used to improve the strength characteristics of wood is by means of laminating. In this process, the discontinuities become randomly distributed. If the number of laminations in a cross section is sufficiently large, the component strength can increase as it approaches the average strength of the species.

The designer must optimize the use of wood components in a wood superstructure. The cost of wood components is a function of many factors. Unlike steel and concrete, the unit cost of wood products is not closely related to volume or strength, but it includes factors related to the volume of various stress grades and sizes recovered in the milling process. Therefore, the judgment and knowledge of the designer, when addressing the classic question of a smaller-sized, higher-

strength component or a larger cross section with lower strength, is central to economic wood bridge design.

The design of wood components includes a number of modification factors not normally associated with steel or concrete. Some of these factors address the variability inherent in wood. Others concern the response of the wood member to all of the environmental factors under which it is to perform. Most of these factors are applied to the base resistance side of the design equation.

One of the modification factors unique to wood-bridge design is the deck factor, C_D. This factor recognizes the load sharing between individual members under certain circumstances. It is applied only to solid sawn members, 2 in. to 4 in. thick, that are used in a structural system that creates load sharing between individual members. *LRFD Specifications* Article 8.4.4.4 recognizes only two applications for this factor, a stressed-wood deck, or a nail-laminated or spike-laminated wood deck.

Another modification factor is the moisture content factor, C_M, as used and specified in *LRFD Specifications* Article 8.4.4.3. For glued-laminated wood, it is considered to be wet if the in-service moisture content is greater than 16%. For such conditions, $C_M = 1.0$. If the in-service moisture content is less than 16%, as indicated in *LRFD Specifications* Table 8.4.4.3-1, the values for C_M are greater than 1.0.

The dynamic load allowance values specified in *LRFD Specifications* Table 3.6.2.1-1 may be reduced 50% for a wood structure.

65-3.02 Solid Sawn Stringers and Glued-Laminated Beams

Reference: Section 8, Various Articles

Analysis of stringers for a stringer-type bridge is specified in Article 4.6.2.2. The distribution of wheel loads for moment in interior beams is shown in Table 4.6.2.2.2b-1. The distribution of wheel loads for moment for exterior beams is shown in Table 4.6.2.2.2d-1. Requirements for the analysis of a wood deck for a stringer-type bridge are included in Article 9.9.

Bracing requirements for wood stringers and glued-laminated beams are provided in Article 8.11.

65-3.03 Spike-Laminated Deck

Reference: Article 9.9.6

A spike- or dowel-laminated deck system consists of longitudinal panels that extend from support to support and produced in a manufacturing process where full-length individually treated planks are mechanically laminated into panels using metal spikes or dowels. The panels are generally 72 in. to 92 in. in width and range in thickness from 8 in. to 16 in. The effective span for design should be taken as the clear distance between supports, plus one-half of the bearing length at each support, but the effective design span should not exceed the clear span plus the deck thickness. For a multi-span bridge, all spans should be designed as simple spans.

The deck is made using a category of solid sawn members classified as dimension lumber. These are planks that are 2 in. to 4 in. in thickness and range in width from 8 in. to 16 in. The base-resistance value for this material is shown in *LRFD* Table 8.4.1.1.4-1. The correct size classification should be used for the material in question. The table includes base-resistance values for size classifications including beams and stringers (B&S), post and timbers (P&T), and dimension lumber. The individual members are cut to length and drilled for the connection hardware prior to treatment with an approved wood preservative.

Calculation of the equivalent strip width for analysis of a spike or dowel-laminated longitudinal deck, for spans greater than 15 ft, is described in Article 4.6.2.3. Determination of equivalent strip width for spans of 15 ft or less is shown in Article 4.6.2.1.3.

The connection between adjacent longitudinal panels should be accomplished using a longitudinal ship-lap joint. The configuration of this type of joint consists of attaching one-half of a laminate to the top half of the facia edge of one panel and the other half of the splice plank to the lower half of the adjacent panel. The primary design consideration for this connection is to provide sufficient shear resistance on the horizontal interface between the two portions of the splice plank to recreate single-member bending resistance of the splice plank. The horizontal shear resistance is developed by driving vertical spikes through the longitudinal ship-lap joint. The spikes are spaced closer together near the supports.

This type of deck design system offers some advantages over other designs. All of the individual laminates are treated prior to assembly into panels so that the resulting bridge component has a large percentage of its volume impregnated with wood preservative over glued-laminated panels. The basic material for the panels is rough sawn planks. By definition, rough sawn material has some dimensional variability. The variability in member thickness is eliminated by surfacing on one side (S1S).

The variability in the depth of the individual members is used to create a surface which is conducive to the adhesion of the asphalt mixture. Once the panels are fabricated, the bottoms of the panels are made smooth, thus forcing all of the variability to the top surface of the completed panel. This provides many gripping surfaces for the asphalt mixture to adhere.

65-3.04 Glued-Laminated Longitudinal Deck

Reference: Article 9.9.4

A glued-laminated deck system consists of vertically-laminated panels which are prefabricated by gluing adjacent laminations together with water-resistant adhesives. The effective span for design should be taken as the clear distance between supports plus one-half of the bearing length at each support. The effective design span should not exceed the clear span plus the deck thickness. For a multi-span bridge, all spans should be designed as simple spans.

This type of longitudinal deck system employs longitudinal glued-laminated panels that extend from support to support and are interconnected with transverse stiffener beams if the span exceeds 8 ft. The panels are about 4 ft in width and vary in depth from 5 in to 14 in. The deck panels are treated prior to shipping to the bridge site. *LRFD Specifications* Article 4.6.2.1.2 provides that, for a slab-type bridge spanning more than 15 ft and that the span is primarily in the direction parallel to traffic, Article 4.6.2.3 should apply for determining equivalent strip widths. For a slab-type bridge spanning 15 ft or less, Article 4.6.2.1.3 should apply. Article 9.9.4.3.1 applies to the design and location of transverse stiffener beams for this type of longitudinal deck system.

65-3.05 Transversely Prestressed Deck

Reference: Article 9.9.5

This type of construction uses solid sawn members that are made to function as an orthotropic plate. One of the advantages of this construction technique is that it allows the use of non-continuous wood laminations, providing that the butt joints are staggered in accordance with *LRFD* Article 9.9.5.3. The controlling attribute in this system is deflection. Consequently, stress grades of material with relatively low strength design values can be used. The additional cost of the rather elaborate post-tensioning system is offset by the use of less costly wood components as described above. The primary load transfer mechanism is the friction between the individual laminates created by the normal force imparted by the post-tensioning system.

There are some concerns to be overcome in the design process. The most serious of these is the loss of post-tension force in the stressing bars due to the non-recoverable creep in the wood components. The level of long-term stress remaining in the bars is a function of many factors, including the number of times the bars are restressed, the time interval between restressing, the stressing sequence, relationship between the stiffness of the prestressing system and the transverse stiffness of the wood, and the type of wood preservative used. The difference between the moisture content of the wood at the time of fabrication, and the resulting equilibrium

moisture content (EMC) of the structure, impacts the long-term stress in the bars in the prestressing system. *LRFD Specifications* Commentary C9.9.5.6.3 includes suggestions for restressing to offset long-term relaxation effects and creep losses.

Deck tie-down requirements for ensuring proper contact of the deck along each support are provided in *LRFD* Article 9.9.5.5.

65-3.06 Wearing Surface for Wood Deck

Reference: Article 9.9.8

An asphalt wearing surface should be used on a wood deck. The asphalt should have a minimum depth of 2 in. and should provide for the cross slope across the bridge. See *LRFD Specifications* Article 9.9.8 for methods of improving the adhesion of the asphalt wearing course and methods to provide a positive connection between the wood deck and the wearing course.

A spike-laminated or stress-laminated wood deck provides an irregular surface with many gripping surfaces for the asphalt mixture to adhere to. The geotextile or tack coat on a spike-laminated or stress-laminated deck should be used if recommended by the manufacturer.

Tension cracks will develop at each bridge support. Traffic tends to create a camelback-type hump at these cracks. This type of crack problem can be prevented by sawing a joint in the wearing surface over each pier and at the ends of the bridge. The joints are then filled and routinely maintained with a rubberized joint material.

A paving strip should be placed along the full length of the bridge at each curbline. The paving strip is to be of treated wood, of width equal to the depth of the asphalt wearing surface at the curbline. This strip has two functions. First, it ensures a uniform thickness at the curbline. Second, it provides a dam in front of the scupper opening that prevents the asphalt mat from yielding and deforming into the scupper opening during the compaction of the asphalt wearing surface on the bridge deck.