United States Department of Agriculture

Standard Plans for Glued-Laminated Timber Bridge Superstructures

Longitudinal Glulam Decks, Stress-Laminated Glulam Decks, Glulam Stringer Bridges, and Transverse Glulam Decks

James P. Wacker
Matthew S. Smith

Forest Service | Forest Products Laboratory | General Technical Report FPL–GTR–260 | November 2019

Abstract

The standardized bridge design aides in this publication are for superstructures manufactured with glued-laminated timber (glulam) that was pressure-treated with preservatives. Four superstructure types are included: two longitudinal (slab-type) deck systems and two transverse deck systems resting on either glulam or steel girders. Simple span designs for both single- and multiple-lane bridges that conform to the American Association of State Highway Transportation Officials (AASHTO)–Load and Resistance Factor Design (LRFD) bridge design specifications are included.

Keywords: timber, glulam, design, standard, bridge, superstructure, AASHTO, LRFD, bridge railing, preservatives

Acknowledgments

The authors recognize and thank the following individuals for their valuable contributions during technical review: James "Scott" Groenier, USDA Forest Service; Art Johnson, retired USDA Forest Service; Jeff Linville of Weyerhauser Company; Tom Williamson of T-Williamson Timber Engineering, LLC; and Guy James of Allegany County Dept. of Public Works, New York. We also recognize and thank Michael A. Ritter for securing funding for this work.

November 2019

Wacker, James P.; Smith, Matthew S. 2019. Standard plans for glued-laminated timber bridge superstructures: Longitudinal glulam decks, stress-laminated glulam decks, glulam stringer bridges, and transverse glulam decks. General Technical Report FPL-GTR-260. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 53 p.

A limited number of free copies of this publication are available to the public from the Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53726-2398. This publication is also available online at www.fpl.fs.fed.us. Laboratory publications are sent to hundreds of libraries in the United States and elsewhere.

The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

Standard Plans for Glued-Laminated Timber Bridge Superstructures

Longitudinal Glulam Decks, Stress-Laminated Glulam Decks, Glulam Stringer Bridges, and Transverse Glulam Decks

James P. Wacker, Research General Engineer
USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin

Matthew S. Smith, Bridge Designer
Laminated Concepts, Inc., Big Flats, New York

Contents

English unit	Conversion factor	SI unit
foot (ft)	0.3048	meter (m)
inch (in.)	25.4	millimeter (mm)
kip (1,000 lbf)	4.448222×10^3	newton (N)
pound, force (lbf)	4.4482	newton (N)
pound, mass (lb)	0.45359	kilogram (kg)
pound per cubic foot (lb ft^{-3})	16.02	kilogram per cubic meter (kg m^{-3})
pound per square inch (lb in^{-2})	6.89	kilopascal (kPa)
square inch (in^2)	645.16	square millimeter (mm^2)

Chapter 1

Introduction

1.1 Use of Wood for Bridges

Throughout history, wood has been used as a means for crossing obstacles, such as streams, rivers, or uneven terrains. From the earliest use of fallen trees as makeshift bridges to today's advancement of pre-engineered timber products, wood has proven itself time and time again to be a readily available material suited for the task at hand.

Wood has performed successfully as a material for transportation structures such as bridges. It has been used from the early pioneers felling trees while clearing their farmlands to railroads, which led to the use of preservative-treated members for cross ties and railroad trestles. Untreated timber found much success in the designs of covered bridges, many of which have achieved life spans of more than 100 years.

Other materials such as steel and concrete have made significant strides as a preferred material for this nation's hundreds of thousands of highway bridges, yet these materials have their own pitfalls. In colder climates, chlorides are used as de-icing materials on bridge decks. This has proven to dramatically decrease the life expectancy of those structures. Also, the more sophisticated the materials become, the more specialized the labor force needs to be to install the structures.

Timber has also advanced through the years, especially in the technologies of "engineered" timber (for example, glued-laminated timber and wood composites) (AITC 2018) and the preservative treatment process. And with clear, high-quality designs, laborers, owners, and municipalities find installations to be within their budgets and skill levels.

1.2 Codes and Standards

The American Association of State Highway Transportation Officials (AASHTO) sets design criteria for bridge structures in the United States (AASHTO 2018). In 2007, AASHTO required the use of the Load and Resistance Factor Design (LRFD) methodology.

This publication was developed to provide simplified information to facilitate the design of glued-laminated timber (glulam) bridges according to the adopted LRFD methodology. This publication presents span charts for four common bridge constructions using structural glulam.

The manufacturing of glulam in the United States is governed by the American National Standard Institute (ANSI) A190.1-2012 and is supervised by APA–The Engineered Wood Association.

For the bridge types shown in this publication, the latest preservative treatment standards as issued by The American Wood Protection Association (AWPA 2018b) will be referenced and used.

The American Association of State Highway and Transportation Officials
APA–The Engineered Wood Association
American Wood Protection Association

1.3 Purpose and Use of this Publication

Many types of timber designs are used as bridge crossing structures. Each has specific advantages regarding depths, strengths, and economics. This publication focuses on four proven glulam bridge superstructures:

- Longitudinal glulam decks
- Stress-laminated glulam decks
- Glulam stringers
- Transverse glulam decks

The information included will provide prospective owners, developers, contractors, design engineers, or municipality superintendents with basic information needed to make an educated selection of the bridge superstructure best suited to their applications. A more complete set of design and construction drawings and specifications for the bridge location should be developed under the supervision of a licensed professional engineer.

All designs for the bridge superstructures herein are based on AASHTO LRFD Bridge Design Specifications (AASHTO 2017a) and include the most realistic conditions that those structures are expected to withstand during their service life.

Each type of structure has been designed for its proposed maximum span lengths (from 20 to 80 ft, depending on design type) and will depict two roadway widths, single lane (12 ft) and multilane (24 ft), all designed to the AASHTO LRFD loading of HL93 (see Chapter 5).

Each bridge type will include design span charts as well as conceptual drawings and construction details for the structure. With this information, designers can save time in their design process. Guidance is also provided for crash-tested timber bridge railing systems and asphalt wearing systems. Multiple-span continuous timber bridge designs and substructure designs are beyond the scope of this document. Complementary information, including design examples and construction videos, are available online through the National Center for Wood Transportation Structures (www.woodcenter.org).

This publication is a follow-up to the prior USDA publication “Standard Plans for Timber Bridge Superstructures” (Wacker and Smith 2001). That document, which covers seven superstructure types, including glulam and sawn lumber bridge systems, was prepared using allowable stress design procedures outlined in “Standard Specifications for Highway Bridges, 17th edition” (AASHTO 2002).

Chapter 2

Materials

2.1 Structural Glued-Laminated Timber

Structural glulam is an engineered wood product made by bonding structural lumber to create larger members. Individual pieces of lumber are joined end to end using structural finger joints to create continuous laminations for the full length of the laminated member. Each layer consists of one or more pieces of lumber across the width. Edge joints between pieces may or may not be bonded depending on the structural requirements of the member.

Design values for glulam depend on the orientation of the laminations relative to applied loads. The bending axis parallel to the bond line is designated as the x–x axis, and the bending axis perpendicular to the bond line is designated as the y–y axis (Fig. 2.1).

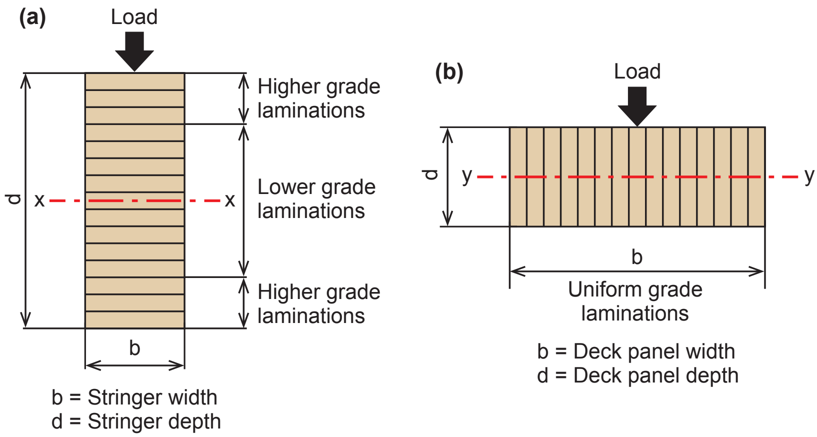


Figure 2.1. Glulam loading conditions: (a) stringer layup; (b) deck layup.

For bridge applications, the design of stringers and beams is typically based on glulam members loaded in bending primarily about the x–x axis and using allowable design values from combination symbols (AASHTO 2017a, table 8.4.1.2.3-1). Glulam decks are designed for bending about the y–y axis and using design values from identification numbers (AASHTO 2017a, table 8.4.1.2.3-2). Wet-use adhesives and pressure treatments are required for nearly all highway bridge applications.

Glulam timbers are permitted to be manufactured from a single grade of lumber or with multiple grades placed throughout the cross section. Deck panels are typically manufactured using a uniform grade layup, because all laminations are stressed similarly. Stringers and beams are typically manufactured with higher grades of lumber placed near the top and bottom surfaces and lower grades placed in the core of the beam. In addition, the bottom of the beam may have higher grades of lumber than the top, resulting in different design values for positive and negative bending.

There are three different glulam layering configurations based on the stringer–beam width or deck panel depth (Fig. 2.2). For beams up to 10-3/4 in. wide or decks up to 10-3/4 in. thick, glulam members are typically manufactured from single-piece laminations across the width. For greater widths, each lamination typically consists of two or more pieces across the width with the edge joints staggered between adjacent layers. The staggered edge joints are left unbonded unless bonding is specified to meet structural requirements. If the edge joints are not bonded, a decreased shear design value is used for bending about the y–y axis.

Glulam in the United States is primarily manufactured from two species combination groups: Douglas Fir–Larch (DF) and Southern Pine (SP). This publication presents design drawings and specifications for bridges based on common glulam layups from these two species combination groups.

Standard finish sizes of members differ between DF and SP glulam. DF glulam is typically manufactured from 1-1/2-in.-thick laminations; therefore, standard beam depths (or deck panel widths) are multiples of 1-1/2 in. SP laminations require additional surfacing for proper bonding; therefore, standard beam depths are multiples of 1-3/8-in.-thick laminations. The two species groups are also typically surfaced to different finished widths (Table 2.1).

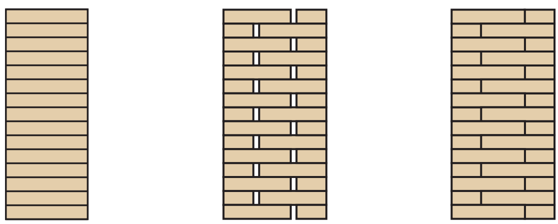


Figure 2.2. Glulam timber layup types.

Table 2.1—Glulam timber finish width chart

Southern Pine finished width (in.)[a]	Douglas Fir–Larch finished width (in.)[a]	Ply layup
3	3-1/8	single
5	5-1/8	single
6-3/4	6-3/4	single
8-1/2	8-3/4	single
10-1/2	10-3/4	single
12	12-1/4	multi
14	14-1/4	multi
16	16-1/4	multi

[a]Finished width of beam and finished depth of deck.

2.2 Preservative Chemicals

Over the years, great advancements in the quality of timber preservation treatments have been made. It is required that glulam bridge members be pressure-treated with preservatives to achieve good durability in accordance with requirements of AASHTO M133 (AASHTO 2017b).

Extensive field testing has indicated that when properly treated, glulam can provide a very durable bridge component. Glulam bridge timbers should be treated with a preservative with heavy oil as its carrier. Heavy oils aid in the protection of the wood by increasing water repellency but require a post-treatment process (treated after gluing). Other treatments are available using lighter oil carriers. These treatments are primarily used for a pretreating process (treated before gluing) but can be applied after gluing with lesser water repellent protection than the heavy oil.

As much as practical, all bridge components should be fabricated (holes drilled, cuts made, etc.) before the preservative treatment process. If field fabrication is required, all cuts, holes, etc., must be field treated in accordance with AWPA Standard M4 (AWPA 2018a).

Treatments such as pentachlorophenol, copper naphthenate, and creosote are the most widely accepted preservatives for glulam bridge use. Treatment processes should conform to “Best Management Practices (BMP) for Preservative Treated Wood in Aquatic Environments” (WWPI 2012).

The main governing body for treated timber is the AWPA. Designers should reference the use category standards as described in “Use Category System U1” (AWPA 2018c) for the proper types, applications, and retentions of preservative treatments for their bridge structure (see Section 5.1).

2.3 Structural Steel and Hardware

Steel and hardware for timber bridge structures is manufactured from mild steel meeting the requirements of American Society for Testing and Materials (ASTM) Standard A36 for steel shapes and plates and ASTM A307 for threaded connectors (ASTM 2017).

Bolts and lag screws must meet the size and quality requirements of American Society of Mechanical Engineers (ASME) B18.2.1 (ASME 2012). Some bridge hardware, such as high-strength bars for stress-laminated applications, must be manufactured from higher strength steel material as outlined in AASHTO M275 and ASTM A722.

All steel hardware must be hot-dipped galvanized according to the appropriate AASHTO and ASTM requirements. Galvanizing of stressing bars should also follow the recommendations of the bar manufacturer so as not to adversely affect the mechanical properties of the high-strength steel. Galvanized nuts should be retapped to accept the increased diameter of the bar caused by galvanizing. Stainless steel hardware may be used in lieu of hot-dipped galvanized hardware if the hardware will be subjected to salt water exposure or salt-based preservative treatments.

For connections securing wood-to-wood members, dome-head bolts are used to minimize bolt head protrusion exposed to traffic as well as to provide a large bearing surface area for the bolt. Timber, ogee, dock, or other large-diameter washers are used at the nut end of the bolts.

For connections bolting steel to wood, hex-head bolts with flat cut washers are primarily used.

Hand wrenching or using impact wrenches to secure the bolts tightly to the timber member is all that is required for installation. Meeting a specific torque value is not required. Caution: hand wrenching is recommended at installation because the glulam members will initially gain moisture in service causing minor swelling action. Checking all connections for tightness at the first annual inspection is also recommended.

See Chapter 5 for material specifications for steel shapes, bolts, and other connecting hardware required for glulam bridge superstructures.

Chapter 3

Design Plans, Details, and Data Charts

3.1 Longitudinal Glulam Decks

Longitudinal glulam decks (Fig. 3.1) offer the designer a cost-efficient way to cross short spans for which hydraulic or headroom clearances require a shallow-depth superstructure. With little or no reworking of the existing abutments, these structures are ideal for replacement structures.

As the name implies, longitudinal glulam deck panels span longitudinally between supports, forming both the superstructure and the deck for the bridge. Load distribution beams, or stiffeners, run transversely under the deck to decrease differential deflection between the longitudinal deck panels (Fig. 3.2).

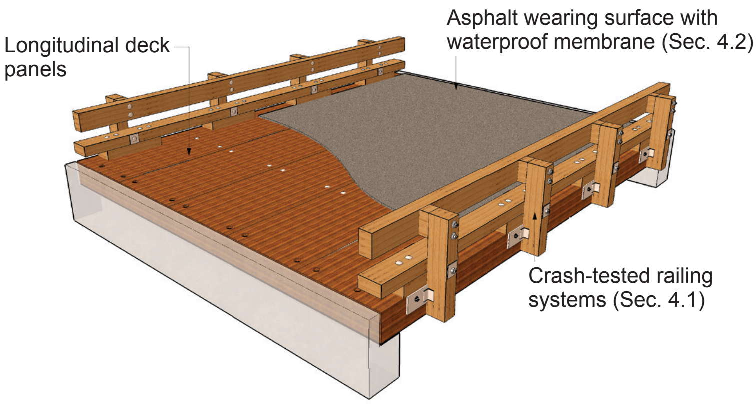


Figure 3.1. Perspective top view of a longitudinal glulam deck.

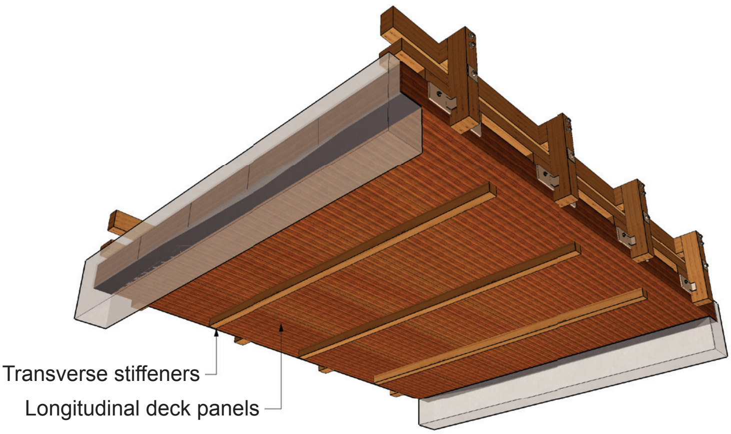
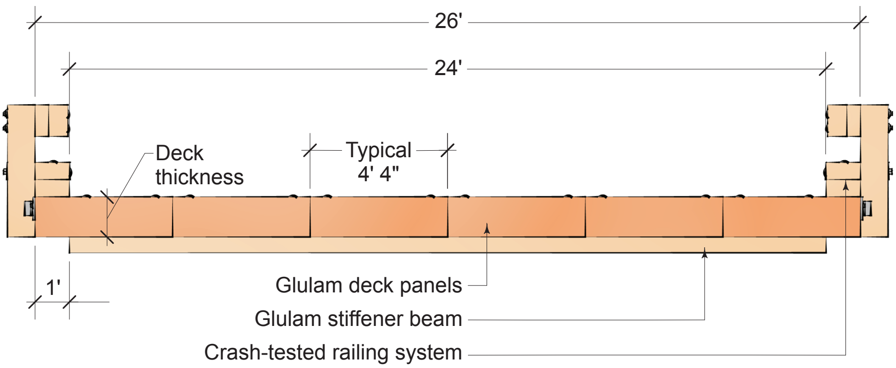


Figure 3.2. Underside perspective view of a longitudinal glulam deck.

The longitudinal glulam deck charts (Figs. 3.3 and 3.4) show the maximum design span for a given deck thickness and species, according to the following assumed design parameters:

- HL93 live load
- 6-in. uniform asphalt layer
- Multilane width of 24 ft (Fig. 3.3)
- Single lane width of 12 ft (Fig. 3.4)
- SP identification 48 layup
- DF identification 2 layup
- *L*/425 deflection limit
- Wet-stress reductions applied
- Simple span design
- Nonedge-glued panels (12 in. thick and greater)



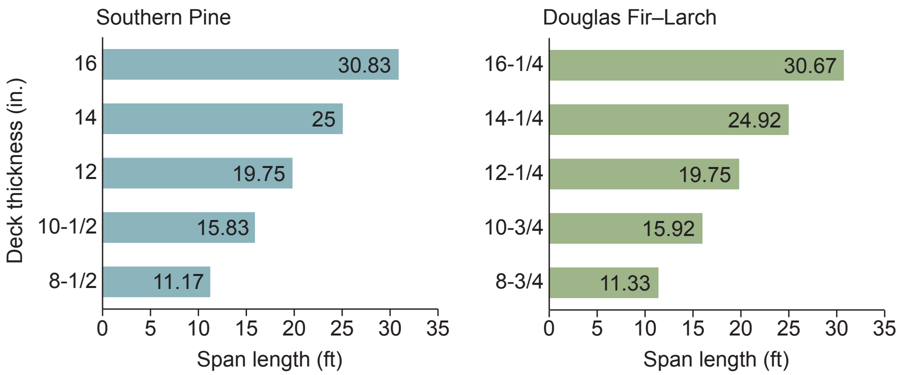


Figure 3.3. Longitudinal glulam deck section and span charts for multilane bridges (on this and all similar figures, fasteners and asphalt wearing surface were omitted for clarity).

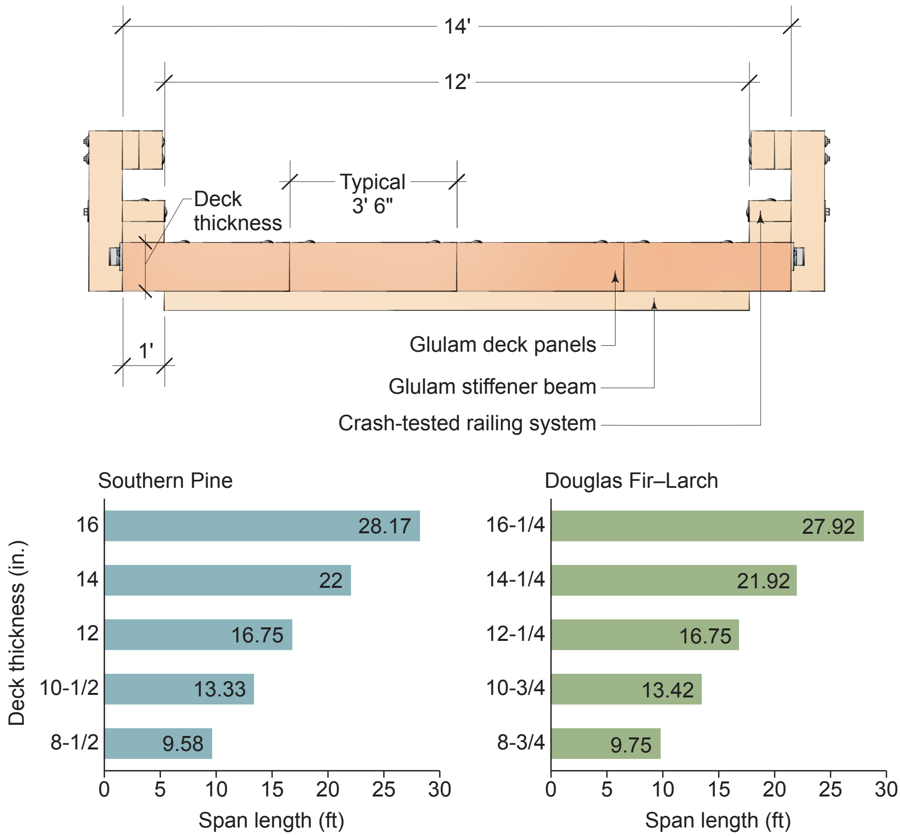


Figure 3.4. Longitudinal glulam deck section and span charts for single lane bridges.

AASHTO requires that the spacing of transverse stiffener beams does not exceed 8 ft on center (Fig. 3.5). In addition, the flexural stiffness, EI (E, Youngs modulus of elasticity; I, member moment of inertia, in^4), of each stiffener must be at least 80,000 kip-in^2 (1 kip = 1,000 lb).

Stiffeners are attached to the deck panels by 3/4-in.-diameter dome-head through-bolts. The bolts are placed a distance of 6 in. from the panel edge and then spaced at a maximum of 15 in. on center (Fig. 3.6).

The stiffeners are fabricated with slotted holes for deck attachment measuring approximately 2 by 13/16 in. When environmental or moisture changes occur throughout the service life of the bridge, the slots allow for small movements in the deck.

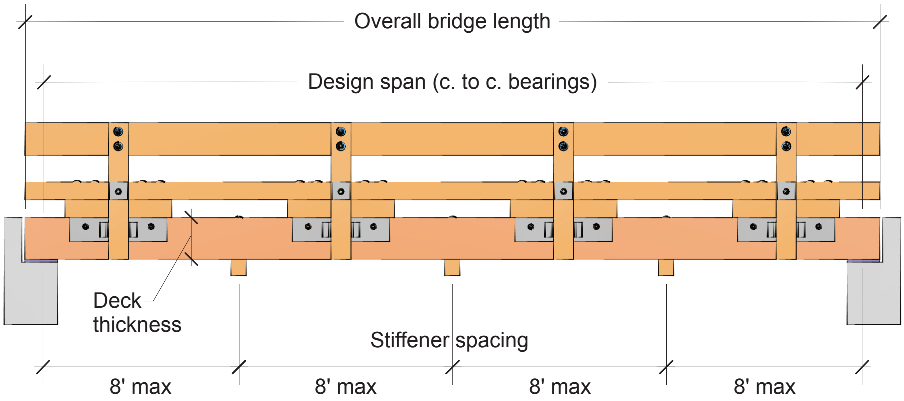


Figure 3.5. Longitudinal glulam deck elevation.

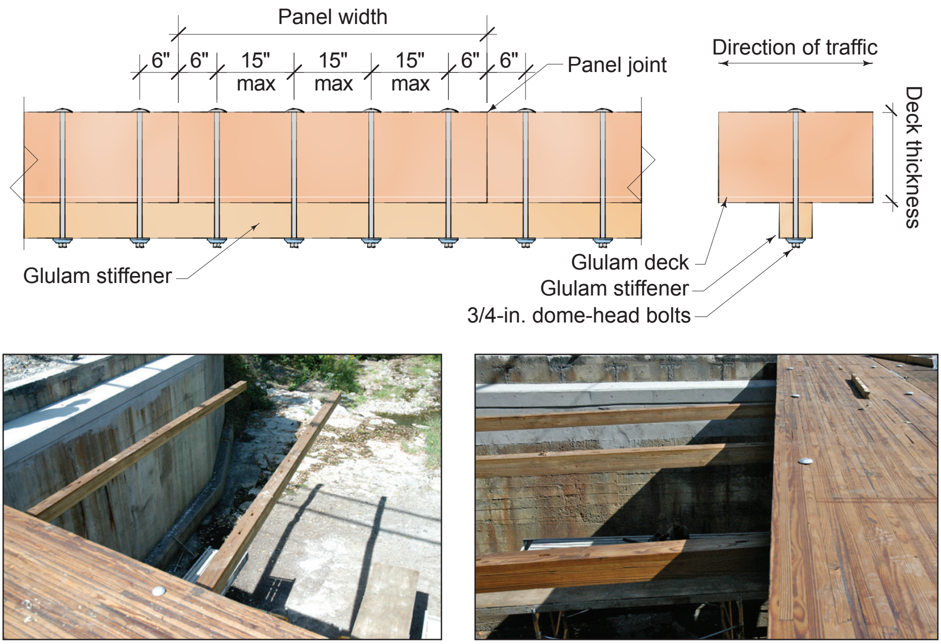


Figure 3.6. Longitudinal glulam deck stiffener details.

On square structures, longitudinal deck panels are manufactured with square ends (Fig. 3.7). The transverse stiffeners are placed and secured perpendicular to the deck panels.

On skewed structures, longitudinal deck panels are manufactured with skewed ends (Fig. 3.8). The transverse stiffeners are placed and secured parallel to the skewed end.

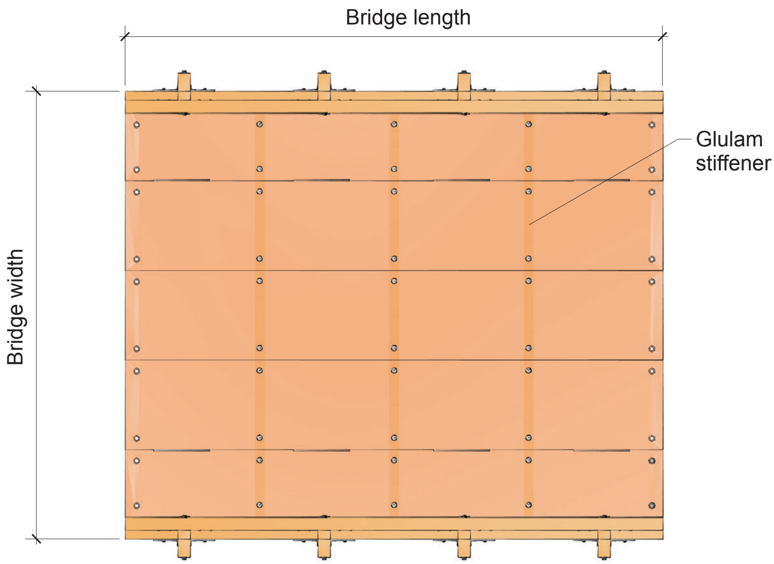


Figure 3.7. Longitudinal glulam deck plan square. Stiffeners run perpendicular to deck panels.

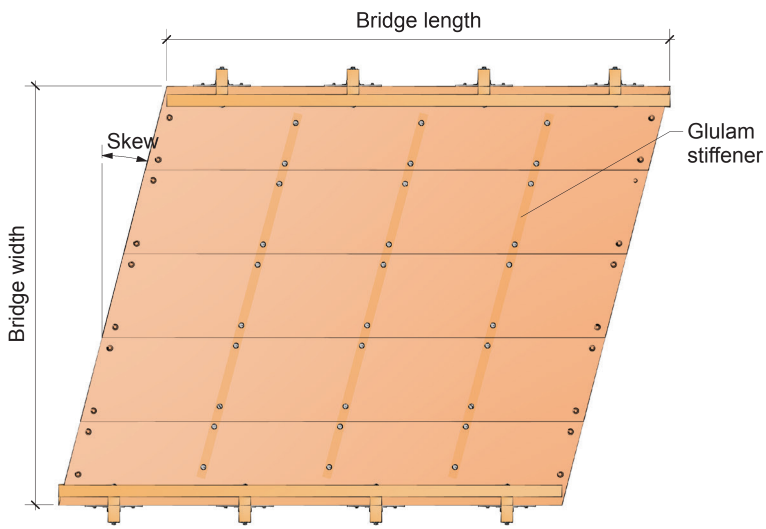


Figure 3.8. Longitudinal glulam deck plan skewed. Stiffeners run parallel to the skew.

Longitudinal glulam deck structures can be supported by all types of abutment materials:

- For concrete abutments, longitudinal deck panels are set and then anchored by field drilling the concrete using the predrilled holes in the panels as guides (Fig. 3.9a). Then, an epoxy or nonshrink grout is applied and anchors are installed.
- When steel bearing angles are used, it is important to provide slotted holes in the angles to compensate for any transverse movement of the panels.
- For timber abutments, the pile cap is field drilled using the predrilled holes in the panel as guides. Field treating the holes in the cap is required before installing the anchor bolts (Fig. 3.9b).
- Steel abutments using channel caps usually require predrilled holes or slots in the cap prior to setting the deck (Fig 3.9c). Field drilling the holes is difficult and not recommended.

Plain neoprene pads, usually 3/4 in. thick, must be used between the bearing surfaces of glulam decks and dissimilar materials such as steel and concrete. Pads may be ordered with anchor holes predrilled, or they may be cut and drilled on site.

Air gaps at the bridge ends will allow exposed end grain of panels to redry more quickly after wetting.

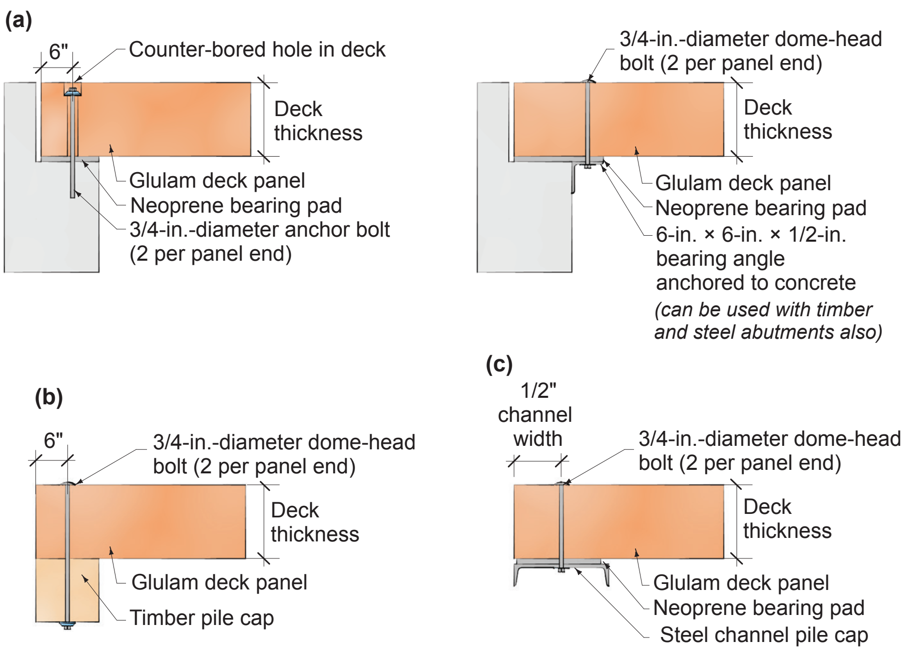


Figure 3.9. Longitudinal glulam deck bearing details: (a) deck to concrete abutment details; (b) deck to wood abutment details; and (c) deck to steel abutment details.

3.2 Stress-Laminated Glulam Decks

Stress-laminated glulam deck bridges offer the same low profile characteristics as the longitudinal deck system with the added benefits of post-tensioning transversely. High-strength tendons (bars) placed in a single row at the neutral axis of the deck apply lateral compressive forces to a group of stringers, thus transforming the individual elements into an efficient orthotropic plate (Fig. 3.10).

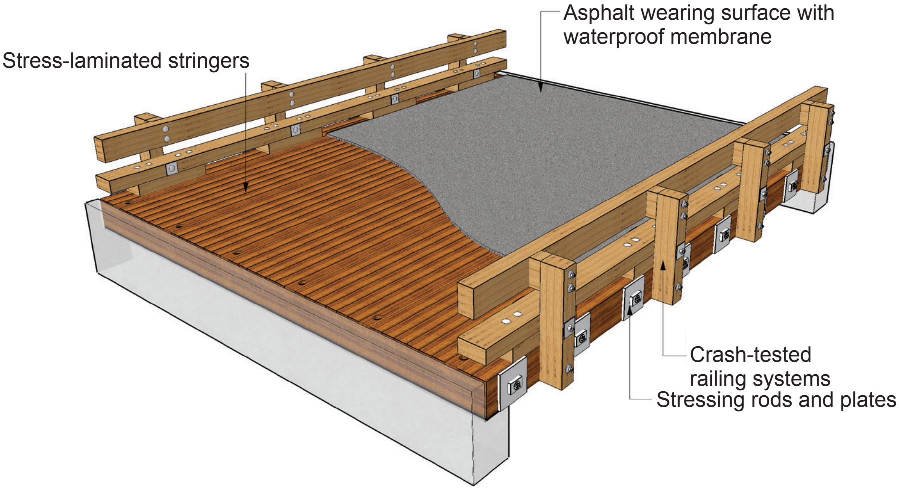


Figure 3.10. Stress-laminated glulam deck.

The individual stringers for the stress-laminated deck run longitudinally, from support to support. The stringers are designed using the values for bending about the x–x axis (Fig. 2.1a). High-strength steel bars, usually a nominal 1 in. in diameter, are placed transversely into predrilled holes and then stressed incrementally to the required stress level.

Most designs of stress-laminated glulam deck bridges use an individual stringer width of 5 in. for SP, 5-1/8 in. for DF, or 6-3/4 in. for either species.

Designers should consider the following:

- Allow enough room on the abutments for ease of assembly and some minor transverse deck swelling.
- Eliminate use of cheek walls at the corners of the bridge superstructure, which can constrain deck swelling across the bridge width.
- Skews should be limited to 15° maximum.
- No bars should be placed within 18 in. of bridge end.

The stress-laminated glulam deck charts (Figs. 3.11 and 3.12) show the maximum design span for a given stringer depth and species, according to the following assumed design parameters:

- HL93 live load
- 6-in. asphalt dead load
- Multilane width of 24 ft (Fig. 3.11)
- Single lane width of 12 ft (Fig. 3.12)
- 5-in. SP combination 24F-V3 stringers
- 5-1/8-in. DF combination 24F-V4 stringers
- *L*/425 deflection limit
- Wet-stress reductions applied
- Simple span design

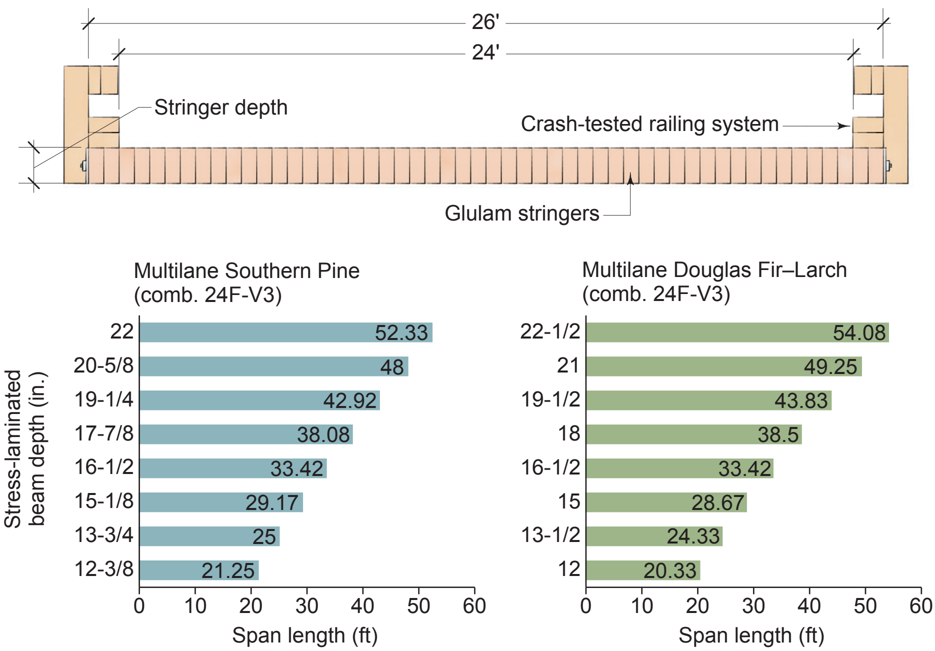


Figure 3.11. Stress-laminated glulam deck section and span charts of multilane bridges.

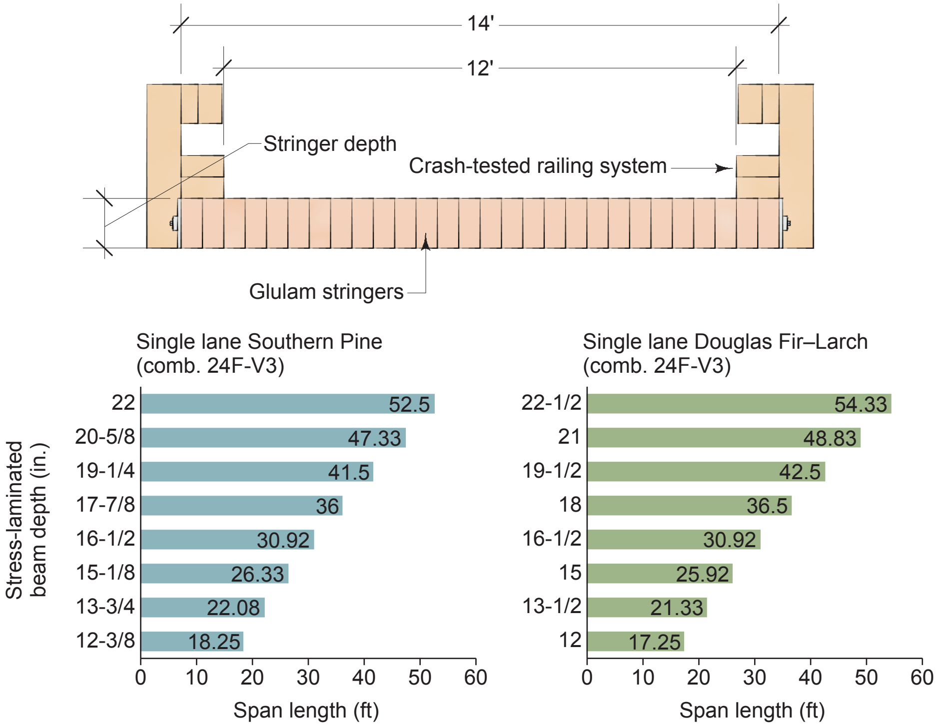


Figure 3.12. Stress-laminated glulam deck section and span charts of single lane bridges.

Stress-laminated glulam decks require the use of high-strength steel bars to achieve and maintain the proper stress level within the deck system. The high stress levels are achieved by using galvanized 1-in.-diameter ASTM A722 steel bars with an ultimate yield stress of 150 kips/in^2, determined by AASHTO LRFD design requirements. These bars are available from a number of suppliers in the United States (Fig. 3.13).

Bearing plates and anchor plates are required to distribute the compression perpendicular-to-grain stresses induced in the timber by the prestressing forces. The dimensions of the plates are determined by calculating the design bar force and applying it against the allowable compression stress of the glulam member.

The maximum spacing for the 1-in.-diameter bars is 4 ft. Also, bars should be spaced to avoid conflicts with the guide rail system. End bars should be placed within 3 ft from the end of the deck.

Stressing bars must be fully tensioned to the determined force in accordance with the following sequence:

• Initial bar tensioning at construction.

• Bar retensioning 1 to 2 weeks after construction tensioning.

• Bar retensioning 6 to 8 weeks after the second tensioning

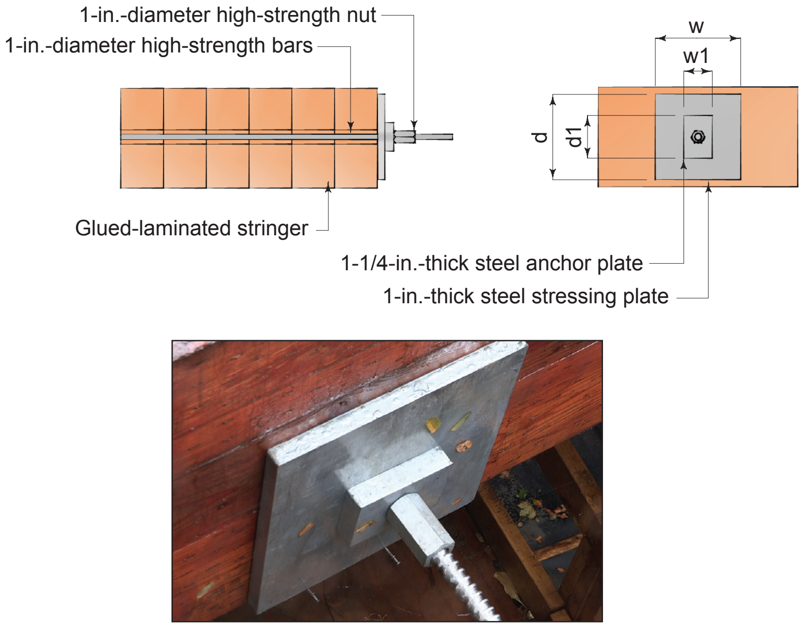


Figure 3.13. Stress-laminated glulam deck stressing detail.

- It is recommended that the bar force be checked on an annual basis for the first 2 years after construction and at 1- to 3-year intervals thereafter. This typically requires little time or equipment and will ensure that the bridge performs properly during the design service life (Ritter and Lee 1996).

Stress-laminated glulam deck structures should not be anchored to the substructure nor should asphalt be applied until after the initial construction tensioning and the first retensioning has been completed.

- For concrete abutments, stress-laminated decks are set then anchored by field drilling the concrete using the predrilled holes in the beams as guides (Fig. 3.14a).
- An epoxy or nonshrink grout is then applied and anchors installed.
- When steel bearing angles are used, it is important to provide slotted holes in the angles to compensate for any transverse movement of the deck.
- For timber abutments, the pile cap is field drilled using the predrilled holes in the beams as a guide. Field treating the holes in the cap is required before installing the anchor bolts (Fig. 3.14b).
- Steel abutments using channel caps usually require predrilled holes or slots in the cap prior to setting the deck (Fig. 3.14c). Field drilling the holes is difficult and not recommended.
- Plain neoprene pads, usually 3/4 in. thick, must be used between the bearing surfaces of glulam decks and dissimilar materials such as steel or concrete. Pads may be ordered with anchor holes predrilled, or they may be cut and drilled on site.

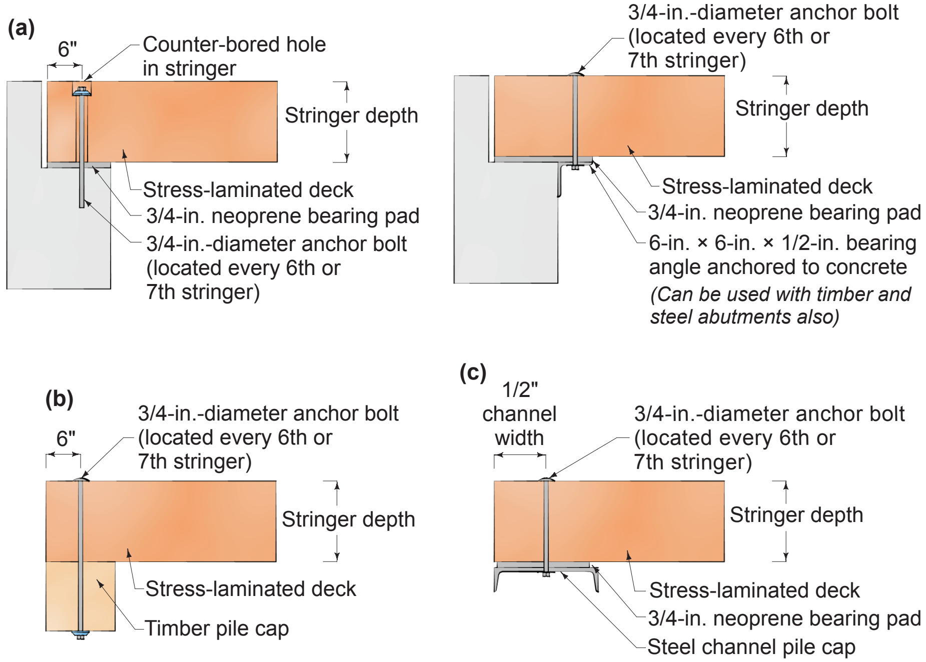


Figure 3.14. Stress-laminated glulam deck bearing details: (a) deck to concrete abutment details; (b) deck to wood abutment details; and (c) deck to steel abutment details.

3.3 Glulam Stringer Bridges

Stringer bridges with transverse glulam decking are probably the most common type of glulam timber bridge structure (Fig. 3.15). For this bridge superstructure system, glulam stringers span longitudinally between the abutments. A panelized glulam deck system is placed transversely on top of the stringers. The glulam components (stringers and transverse deck panels) are interconnected with mechanical fasteners. A bridge railing system that meets FHWA crash testing requirements is installed at the deck edges. Lastly, a protective asphalt layer, in conjunction with a waterproof membrane, is placed over the transverse panels to keep them dry and to provide a durable surface against vehicle wear (see Section 4.2 for more details).

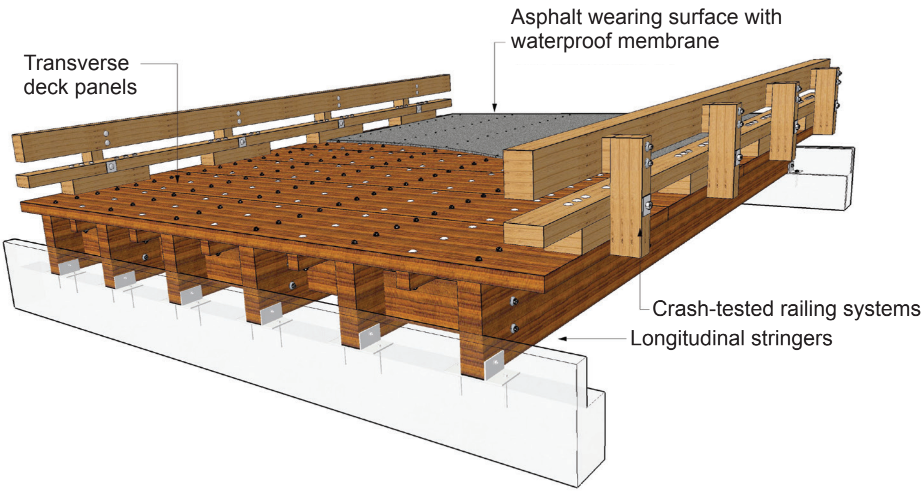
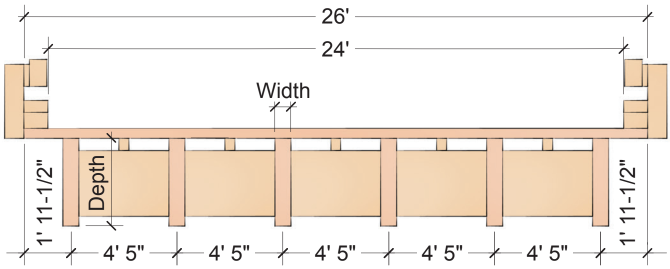


Figure 3.15. Glulam stringer bridge.

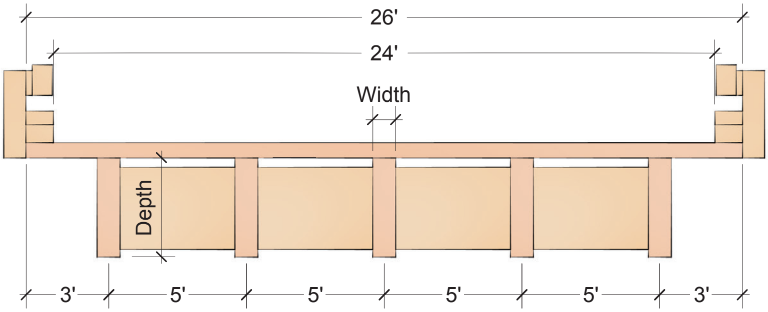
The glulam stringer bridge charts (Figs. 3.16–3.19) show the optimum configuration for a given span length and glulam species combination, according to the following assumed design parameters:

- HL-93 live load
- 6-in. asphalt dead load
- Single lane width of 12 ft (face-face of curb)
- Multilane width of 24 ft (face-face of curb)
- Predetermined deck thickness of 5 and 6-3/4 in. for SYP bridges and 5-1/8 and 6-3/4 in. for DF bridges
- L/425 live load deflection limit
- Dry-stress design values applied to stringers only
- Wet-stress design values apply to all other elements
- Simple span designs



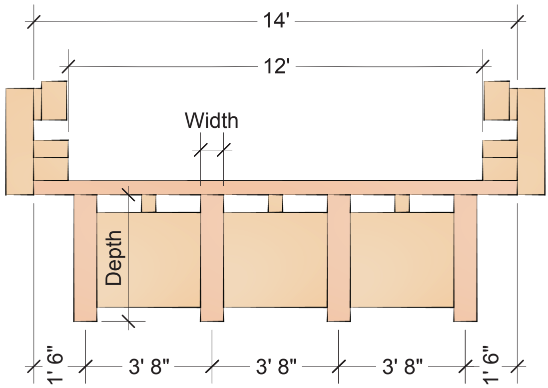
	Southern Pine stringer 24F-V3				Douglas Fir–Larch stringer 24F-V4		
Span (ft)	Width (in.)		Depth (in.)	Span (ft)	Width (in.)		Depth (in.)
24	6-3/4	×	27-1/2	24	6-3/4	×	28-1/2
26			28-7/8	26			30
28			30-1/4	28			31-1/2
30			33	30			34-1/2
32			34-3/8	32			36
34			35-3/4	34			37-1/2
36			37-1/8	36			39
38			38-1/2	38			40-1/2
40			39-7/8	40	8-3/4	×	37-1/2
42	8-1/2	×	38-1/2	42			40-1/2
44			39-7/8	44			42
46			41-1/4	46			43-1/2
48			42-5/8	48			45
50			44	50			46-1/2
52			45-3/8	52			49-1/2
54			48-1/8	54			51
56			49-1/2	56			52-1/2
58			50-7/8	58	10-3/4	×	49-1/2
60	10-1/2	×	48-1/8	60			51
62			49-1/2	62			52-1/2
64			50-7/8	64			54
66			52-1/4	66			57
68			53-5/8	68			58-1/2
70			55	70			60
72			56-3/8	72			61-1/2
74			57-3/4	74			63
76			59-1/8	76			64-1/2
78			60-1/2	78	12-1/4	×	61-1/2
80			61-7/8	80			63

Figure 3.16. Glulam stringer bridge multilane stringer charts, 5-in. Southern Pine deck, 5-1/8 in. Douglas Fir–Larch deck.



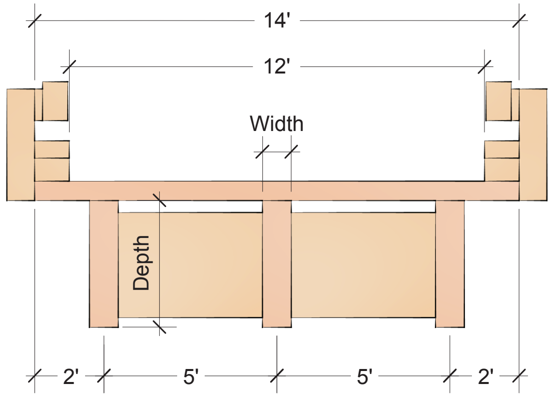
	Southern Pine stringer 24F-V3				Douglas Fir–Larch stringer 24F-V4		
Span (ft)	Width (in.)		Depth (in.)	Span (ft)	Width (in.)		Depth (in.)
24	6-3/4	×	31-5/8	24	6-3/4	×	31-1/2
26			33	26			33
28			34-3/8	28			34-1/2
30			37-1/8	30			39
32			38-1/2	32			40-1/2
34			39-7/8	34	8-3/4	×	37-1/2
36	8-1/2	×	38-1/2	36			39
38			39-7/8	38			42
40			41-1/4	40			43-1/2
42			42-5/8	42			45
44			45-3/8	44			48
46			46-3/4	46			49-1/2
48			48-1/8	48			51
50			50-7/8	50	10-3/4	×	49-1/2
52	10-1/2	×	46-3/4	52			51
54			49-1/2	54			52-1/2
56			50-7/8	56			54
58			52-1/4	58			55-1/2
60			53-5/8	60			58-1/2
62			55	62			60
64			56-3/8	64			61-1/2
66			59-1/8	66			63
68			60-1/2	68	12-1/4	×	60
70			61-7/8	70			61-1/2
72	12	×	59-1/8	72			63
74			60-1/2	74			64-1/2
76			61-7/8	76			67-1/2
78			63-1/4	78			69
80			64-5/8	80			70-1/2

Figure 3.17. Glulam stringer bridge multilane stringer charts, 6-3/4-in. deck.



	Southern Pine stringer 24F-V3				Douglas Fir–Larch stringer 24F-V4		
Span (ft)	Width (in.)		Depth (in.)	Span (ft)	Width (in.)		Depth (in.)
24	6-3/4	×	26-1/8	24	6-3/4	×	27
26			27-1/2	26			28-1/2
28			28-7/8	28			30
30			30-1/4	30			31-1/2
32			33	32			34-1/2
34			34-3/8	34			36
36			35-3/4	36			37-1/2
38			37-1/8	38			39
40			38-1/2	40			40-1/2
42			39-7/8	42	8-3/4	×	37-1/2
44	8-1/2	×	37-1/8	44			39
46			39-7/8	46			42
48			41-1/4	48			43-1/2
50			42-5/8	50			45
52			44	52			46-1/2
54			45-3/8	54			48
56			46-3/4	56			49-1/2
58			48-1/8	58			51
60			49-1/2	60	10-3/4	×	48
62			50-7/8	62			49-1/2
64	10-1/2	×	48-1/8	64			52-1/2
66			49-1/2	66			54
68			50-7/8	68			55-1/2
70			52-1/4	70			57
72			53-5/8	72			58-1/2
74			55	74			60
76			56-3/8	76			61-1/2
78			57-3/4	78			63
80			59-1/8	80			64-1/2

Figure 3.18. Glulam stringer bridge single lane stringer charts, 5-in. Southern Pine deck, 5-1/8-in. Douglas Fir–Larch deck.



	Southern Pine stringer 24F-V3				Douglas Fir–Larch stringer 24F-V4		
Span (ft)	Width (in.)		Depth (in.)	Span (ft)	Width (in.)		Depth (in.)
24	6-3/4	×	28-7/8	24	6-3/4	×	30
26			30-1/4	26			31-1/2
28			33	28			34-1/2
30			34-3/8	30			36
32			35-3/4	32			37-1/2
34			37 1/8	34			40-1/2
36			39-7/8	36	8-3/4	×	37-1/2
38	8-1/2	×	37-1/8	38			39
40			38-1/2	40			40-1/2
42			39-7/8	42			42
44			42-5/8	44			45
46			44	46			46-1/2
48			45-3/8	48			48
50			46-3/4	50			51
52			49-1/2	52			52-1/2
54			50-7/8	54	10-3/4	×	49-1/2
56			52-1/4	56			51
58	10-1/2	×	49-1/2	58			52-1/2
60			50-7/8	60			54
62			52-1/4	62			57
64			53-5/8	64			58-1/2
66			55	66			60
68			56-3/8	68			61-1/2
70			57-3/4	70			63
72			59-1/8	72			64-1/2
74			61-7/8	74	12-1/4	×	61-1/2
76	12	×	57-3/4	76			63
78			59-1/8	78			64-1/2
80			61-7/8	80			66

Figure 3.19. Glulam stringer bridge single lane stringer charts, 6-3/4-in. deck.

An underside view of the bridge superstructure (Fig. 3.20) reveals that the longitudinal glulam stringers are braced with diaphragms and the transverse deck panels are interconnected with longitudinal stiffeners. Stringer bridges require the use of diaphragms (perpendicular to stringers) for lateral stability and to help resist global deflections. Diaphragms are manufactured from glulam timber or galvanized steel (Fig. 3.21).

Glulam diaphragms are attached to the stringers with 3/4-in.-diameter tie rods. The diaphragms are prefabricated with grooves (ply routs) routed into the interior plies creating a chase running the length of the diaphragm. The diaphragms are offset to each other allowing access to the tie rod nuts and washers.

Galvanized steel diaphragms are manufactured from 3- by 3- by 3/8-in. angles with 3/8- by 3-in. plate diagonals. The diaphragms are attached to the stringers with 3/4-in.-diameter bolts and are installed in alignment.

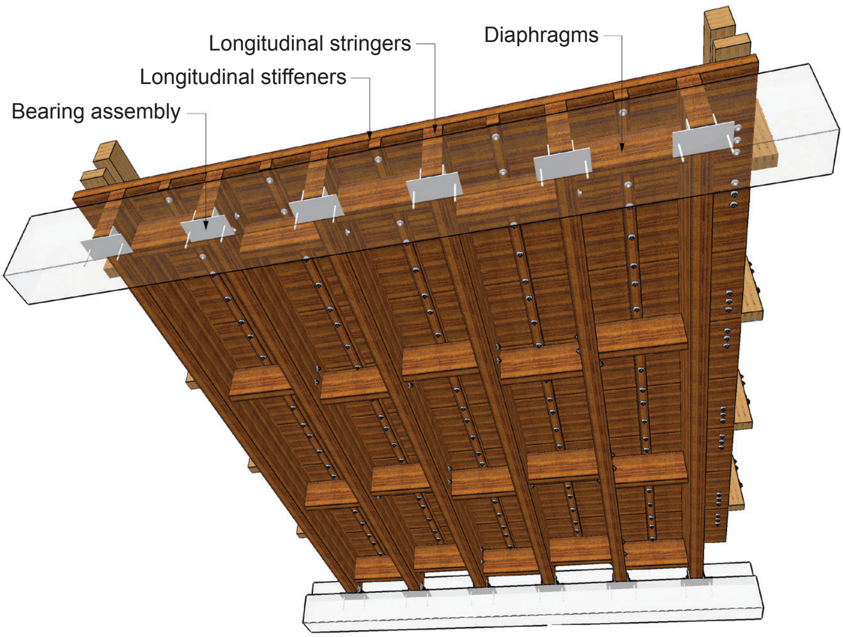


Figure 3.20. Underside view of glulam stringer bridge.

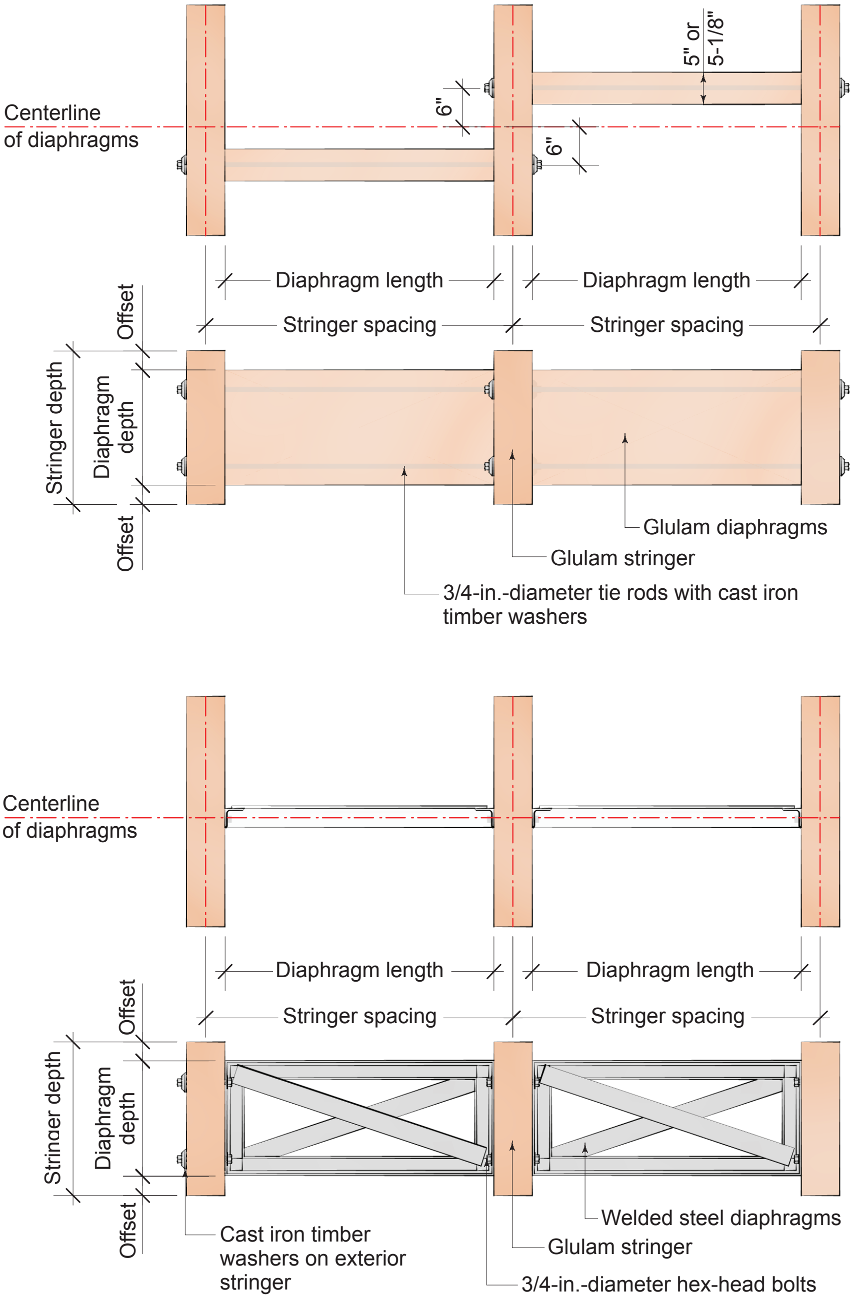


Figure 3.21. Glulam stringer bridge diaphragm details (When using longitudinal stiffeners, the offset distance should equal actual depth of stiffener. If longitudinal stiffeners are not used, offsets should be a minimum of 4 in. at the top and bottom of diaphragm).

The use of longitudinal stiffeners (Fig. 3.22) is recommended with 5-in. and 5-1/8-in. decking to aid in the reduction of differential deflection between the deck panels. The stiffeners are placed midway between and parallel to the stringers. The stiffener is attached to the decking underside with dome-head through-bolts. Stiffeners must run continuous as far as practical. If need be, they can be butt-jointed at a panel midwidth. AASHTO requires that the minimum (EI) value of the stiffener beam be 80,000 kip-in^2.

It is not uncommon for traverse glulam decking to go through minor dimensional changes throughout its service life. Although glulam material is dry when put in service, it may gain moisture, such as humidity from underlying water in hot summer months, causing it to adjust to its microclimate conditions at the bridge site. To allow for these moisture driven fluctuations in panel widths, slotted holes (approximately 2 by 13/16 in.) are provided in stiffeners during prefabrication.

The glulam transverse deck panels are connected to the stringers using one of two fastener options: aluminum deck brackets or lag screws. Both types of fasteners attach the deck directly to the top side of the stringer (Figs. 3.23 and 3.24).

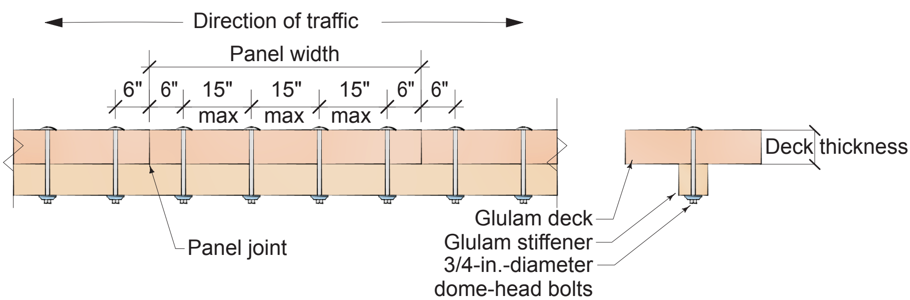


Figure 3.22. Glulam stringer bridge stiffener detail.

The aluminum deck brackets (Fig. 3.25) are available from timber bridge supply companies. Brackets must meet the spacing requirements shown in Figure 3.26. The bolts for attaching the deck bracket are placed 1-1/2 in. from the face of the stringer. Grooves in the stringer may be continuous (full length of stringer) or discontinuous and staggered (8-in.-wide gaps) as illustrated in Figure 3.23. We recommend that the decking be provided with slotted holes (approximately 2 by 11/16 in.) for deck bracket to allow for adjustments during assembly. Deck brackets require 5/8-in.-diameter bolts.

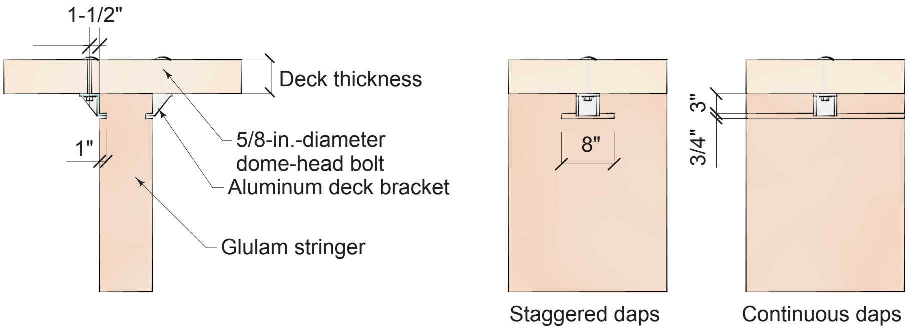


Figure 3.23. Glulam stringer bridge deck to stringer details: aluminum deck bracket.

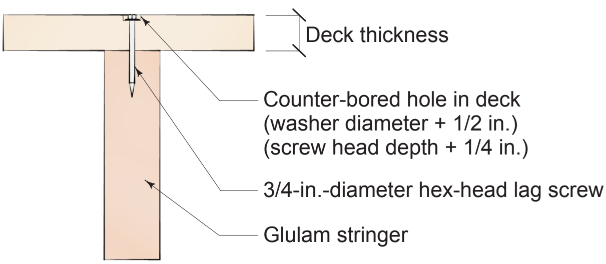


Figure 3.24. Glulam stringer bridge deck to stringer details: lag screw.

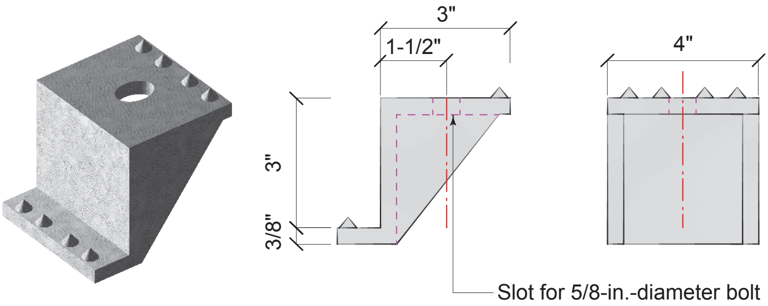


Figure 3.25. Transverse glulam deck aluminum deck bracket for glulam stringers.

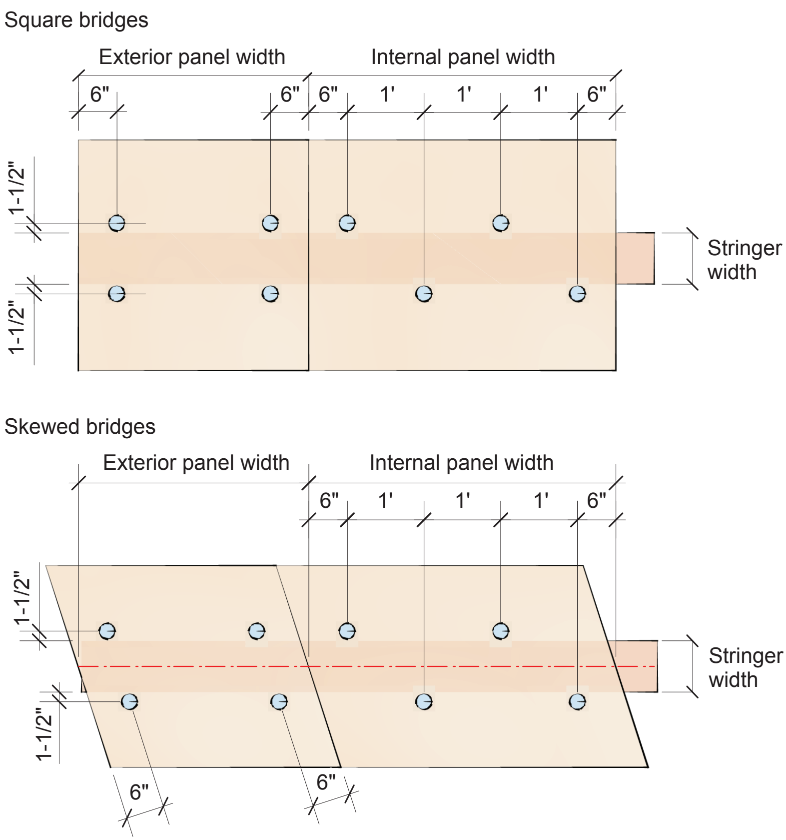


Figure 3.26. Glulam stringer bridge aluminum deck bracket layout.

Attaching the deck panels to the stringers with lag screws (Fig. 3.27) requires field-drilling a pilot hole for the lag screw. The holes in the deck panel must be predrilled with the same diameter as the lags. After setting the deck panel, the predrilled holes are used as a guide to drill lead holes in the stringer. The holes in the stringer should be 1/8 in. smaller than the lag screw diameter. Doing this exposes an untreated hole in the top face of the stringer. *It is imperative* that the lead holes be field-treated according to ASPA Standard M4 prior to installing the lags. Longitudinal stiffener beams must be used if a deck is lagged to the stringers (Fig. 3.22).

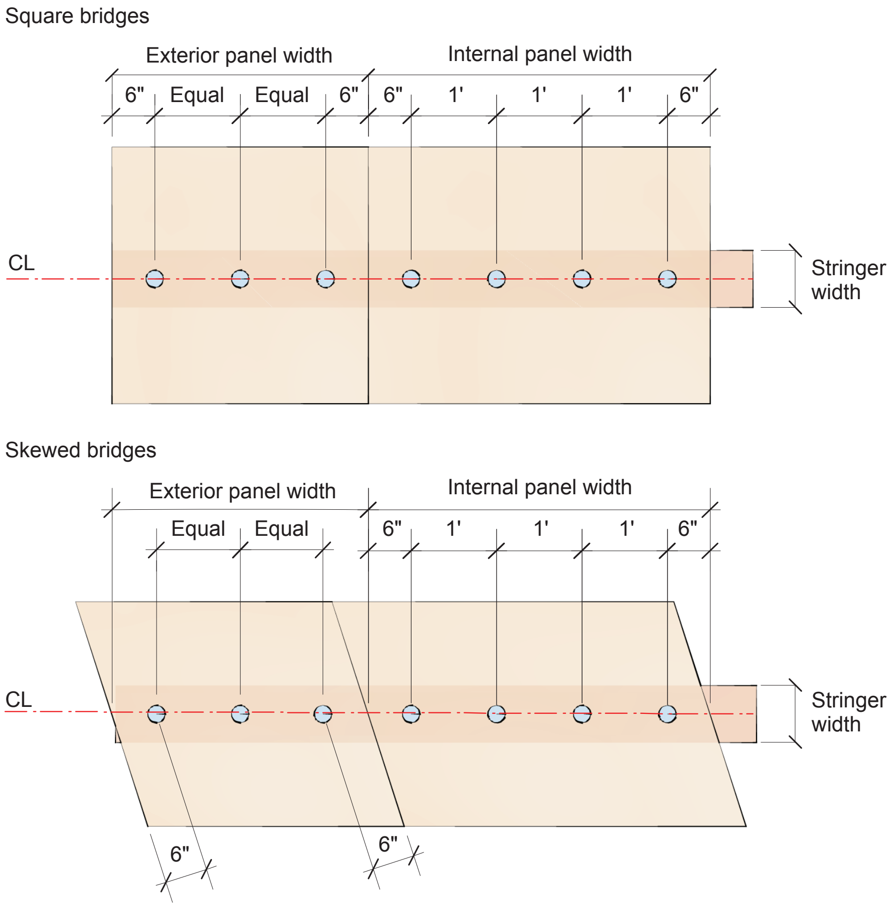


Figure 3.27. Glulam stringer bridge lag screw layout.

Glulam stringer bridge superstructures are anchored to all types of substructure supports (Fig. 3.28).

For concrete and steel abutments, bearings consist of either a one-piece bearing assembly or a flat steel base plate with bearing angles. In either case, a 3/4-in.-thick neoprene bearing pad is placed between the concrete or steel and the glulam stringer. Holes for the anchor bolts are drilled into the concrete after the stringers are set and diaphragms tightened. After cleaning the holes, an epoxy or nonshrink grout is applied and anchors installed. For steel, the bearings can be welded or bolted to the channel in prefabricated slots.

For timber abutments, bearing angles with no neoprene bearing pad are used. Again, the angles are secured to the bearing cap with 3/4-in.-diameter bolts after the stringers are set and diaphragms tightened.

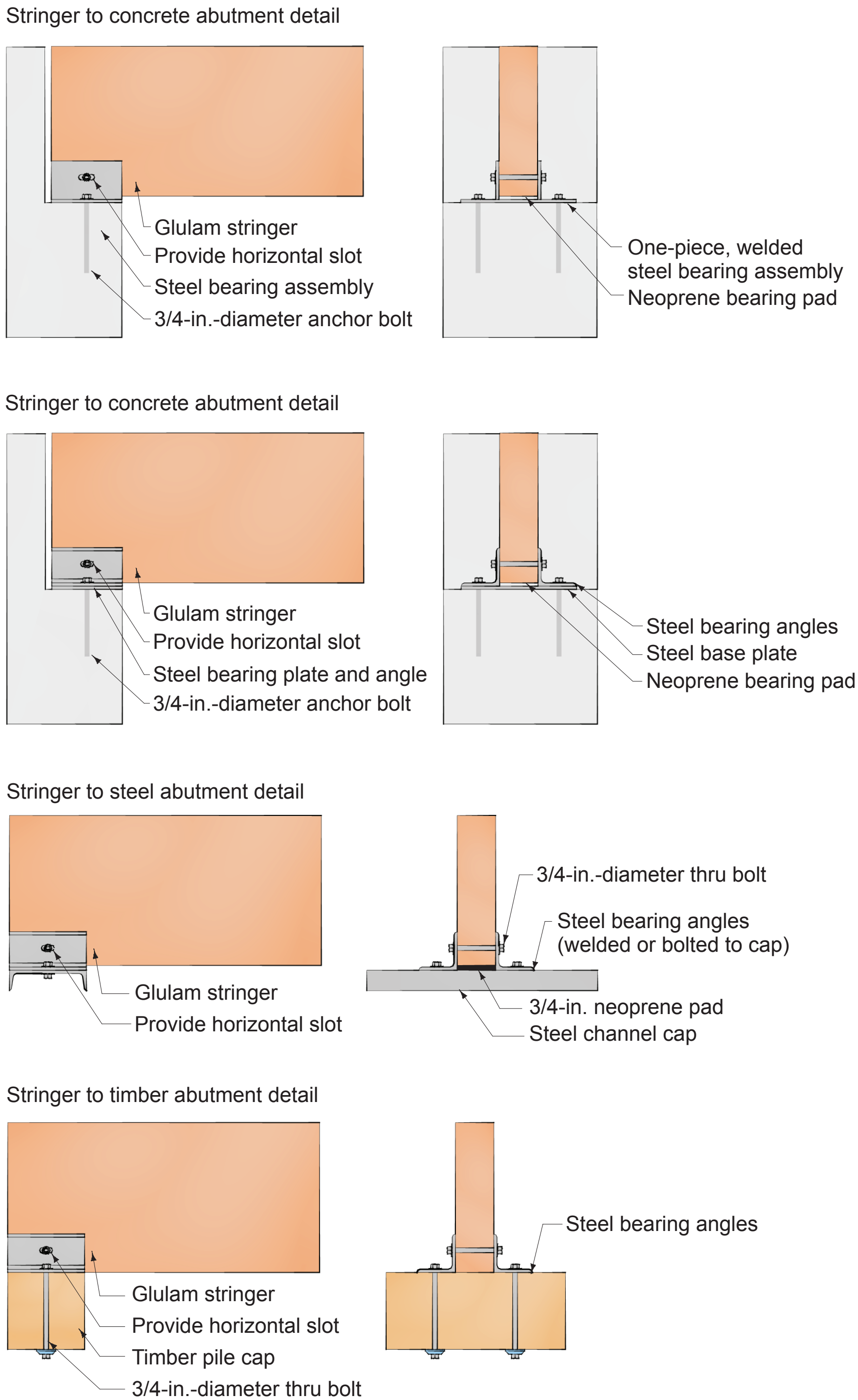


Figure 3.28. Glulam stringer bridge bearing details.

3.4 Transverse Glulam Decks

Transverse glulam decking consists of glulam deck panels oriented across supporting beams (stringers). Glulam decking has been successfully used with timber, steel, and concrete stringers (Fig. 3.29). The deck is attached to the stringers using specialty connectors available from timber bridge supply companies.

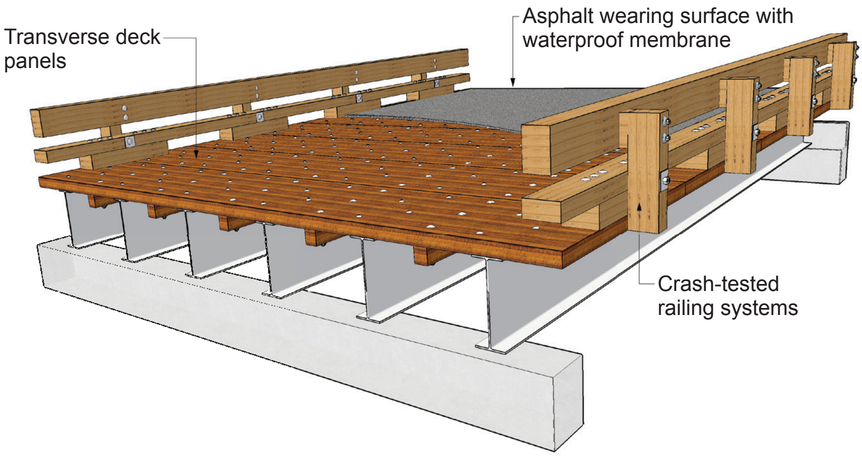


Figure 3.29. Transverse decking on steel stringers.

There are two types of transverse glulam decks: interconnected and noninterconnected. Interconnected decks use shear transfer devices between adjacent panels to minimize differential panel deflections. Decks that do not use shear transfer devices are considered to be noninterconnected.

The use of a longitudinal stiffener is recommended as the shear transfer device for both types of decks. The stiffeners are placed midway between stringers. The stiffener is attached to the decking with dome-head bolts and should have slotted holes to allow for transverse movement as the glulam moisture content varies in service (Figs. 3.30 and 3.31).

The transverse glulam deck charts (Fig. 3.32) show the maximum design span and overhangs for a given deck thickness and species, according to the following design parameters:

- HL93 live load
- 6-in. asphalt dead load
- Interconnected and noninterconnected
- Design spans
- *L*/425 and 0.10-in. deflection limits
- Wet-stress reductions apply to all glulam members
- Single span designs

Slots (approximately 2 by 13/16 in.) are provided by the manufacturer in the glulam stiffeners. This allows for movement from any forces caused by panel width changes. AASHTO requires that the minimum EI value of the stiffener be 80,000 kip-in^2. Stiffeners must run continuous as far as practical. If need be, they can be butt-jointed at a panel midwidth. Proper fasteners must be used (Figs. 3.33–3.37).

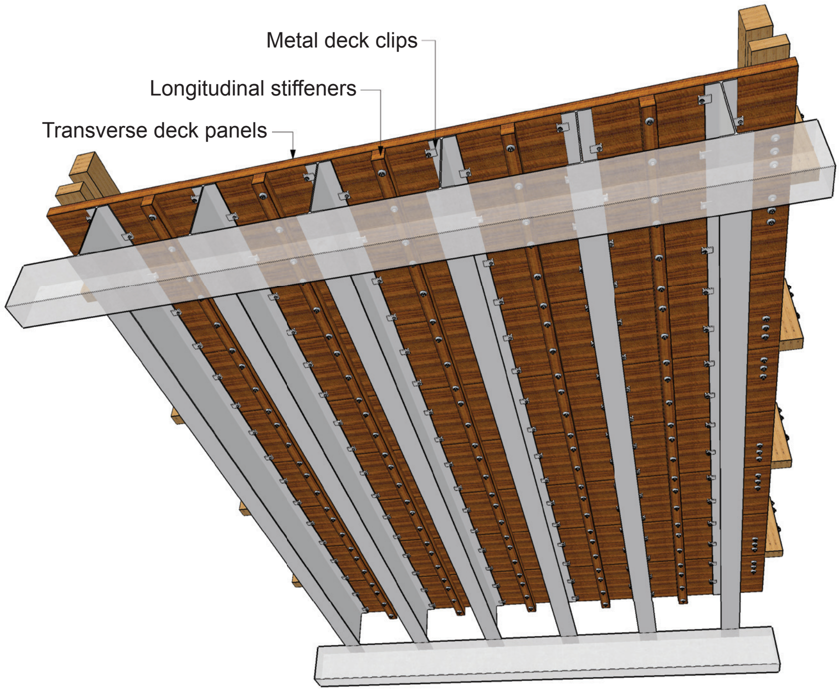


Figure 3.30. Underside of transverse glulam deck.

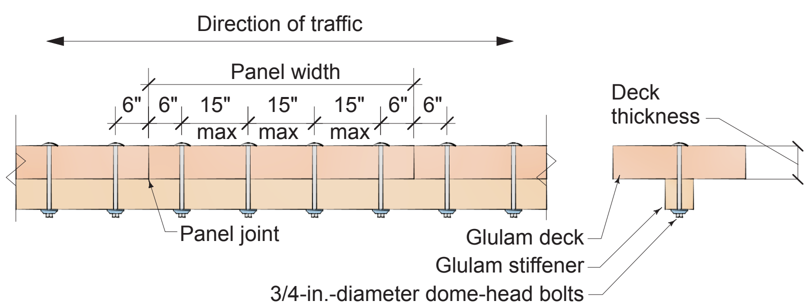
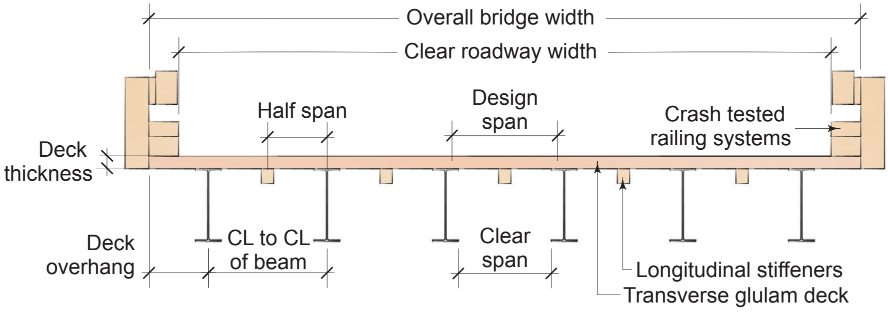


Figure 3.31. Transverse glulam deck stiffener detail.



Design span = clear span + half width of stringer but not to exceed clear span + deck thickness. Deck overhang = center of edge beam to outside edge of deck.

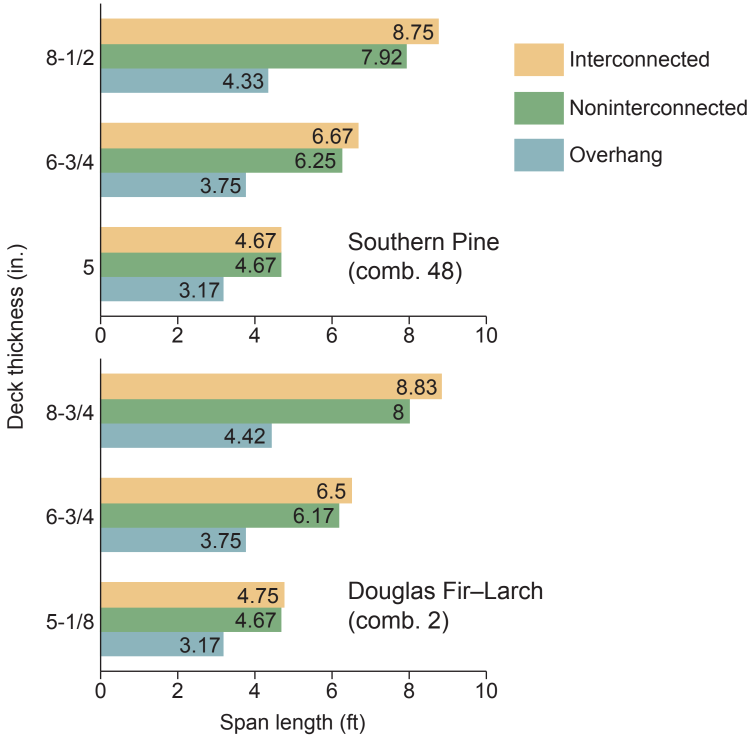


Figure 3.32. Transverse deck span charts.

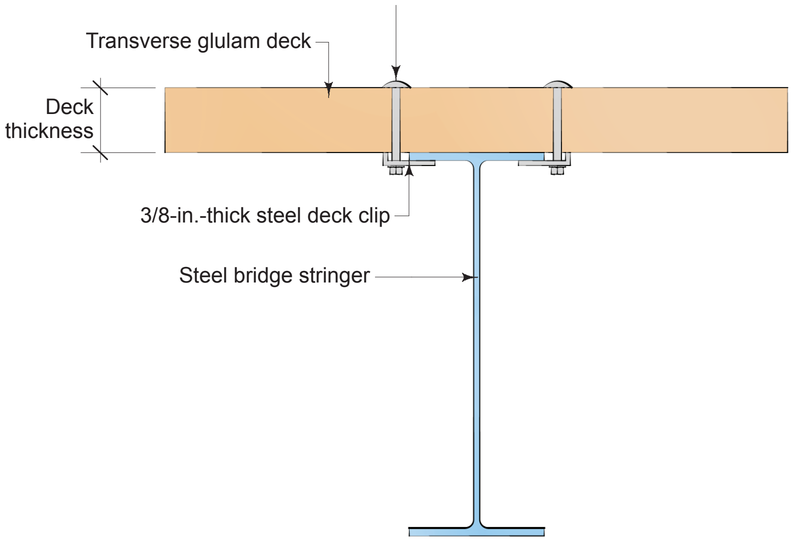


Figure 3.33. Transverse glulam deck to steel detail.

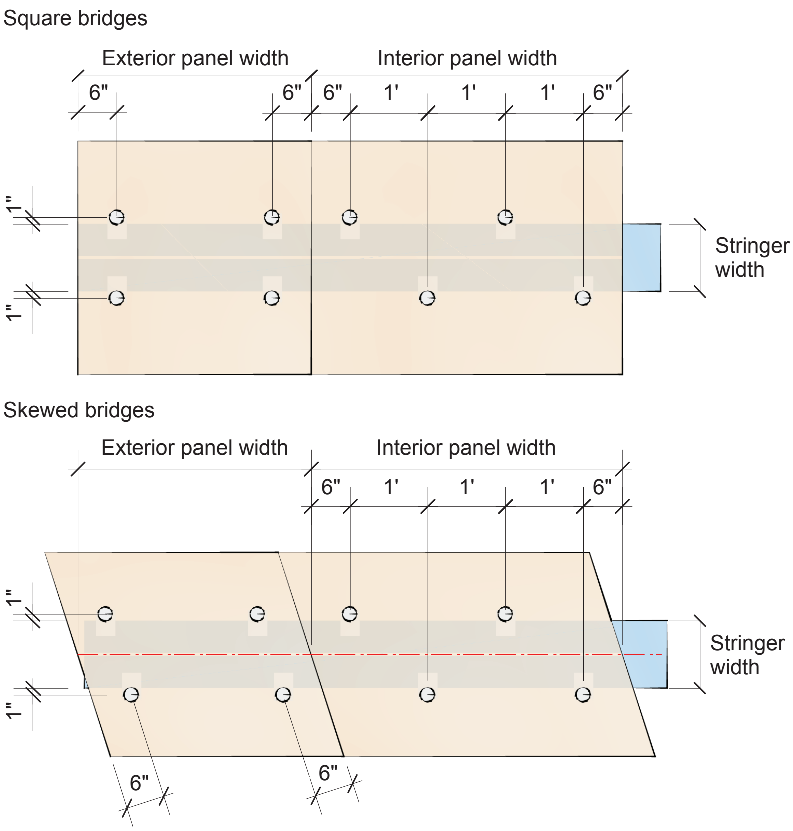


Figure 3.34. Transverse glulam deck clip layout.

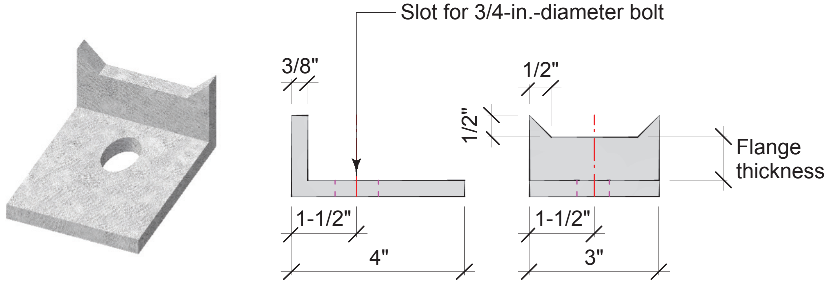


Figure 3.35. Transverse glulam deck steel deck clip for steel stringers (Steel deck clips are suitable for all steel flanges with any thickness.)

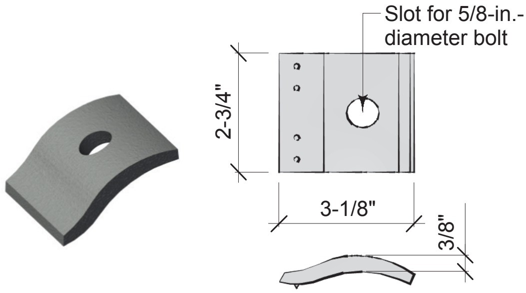


Figure 3.36. Transverse glulam deck cast iron "C" clip for steel stringers. (Cast iron "C" clips are suitable for all steel flanges with a maximum thickness of 3/4 in. Refer to supplier for to the proper hole spacings and layout.)

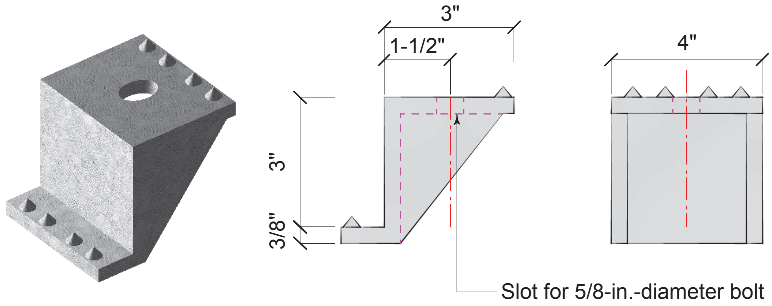


Figure 3.37. Transverse glulam deck aluminum deck bracket for glulam stringers.

Chapter 4

Special Topics

4.1 Glulam Crash-Tested Railings

Fully crash-tested railing systems are approved and available with glulam timber or steel options. Full-scale crash tests were successfully performed, satisfying the criteria for federal bridge funding. Please refer to the Federal Highway Administration (www.fhwa.dot.gov/safety) for additional guidance on bridge railings for timber bridges and new requirements for crash testing methodologies. Strict adherence to size and quality of the lumber, glulam, and hardware components of the crash-tested railing systems is required. Any changes or substitutions to these crash-tested designs require further analysis and approval.

There are many timber crash-tested railing types available:

Longitudinal decks (Fig. 4.1):

- Glulam timber or steel rail with curb, test level 2
- Glulam timber or steel rail without curb, test level 2
- Glulam timber rail with curb, test level 4

Transverse decks (Fig. 4.2):

- Glulam or steel rails, test level 2,
- Glulam timber or steel rails, test level 4

The following are publications about crash-tested rail documentation:

- "Plans for Crash-Tested Wood Bridge Railings for Concrete Decks" (Ritter and others 1998b)
- "Two Test Level 4 Bridge Railing and Transition Systems for Transverse Timber Deck Bridges" (Faller and others 2000)
- "Plans for Crash-Tested Bridge Railings for Longitudinal Wood Decks on Low-Volume Roads" (Ritter and others 1998a).

Primarily, all glulam structures use glulam or solid timber railing elements; however, there are crash-tested design options using steel rail components.

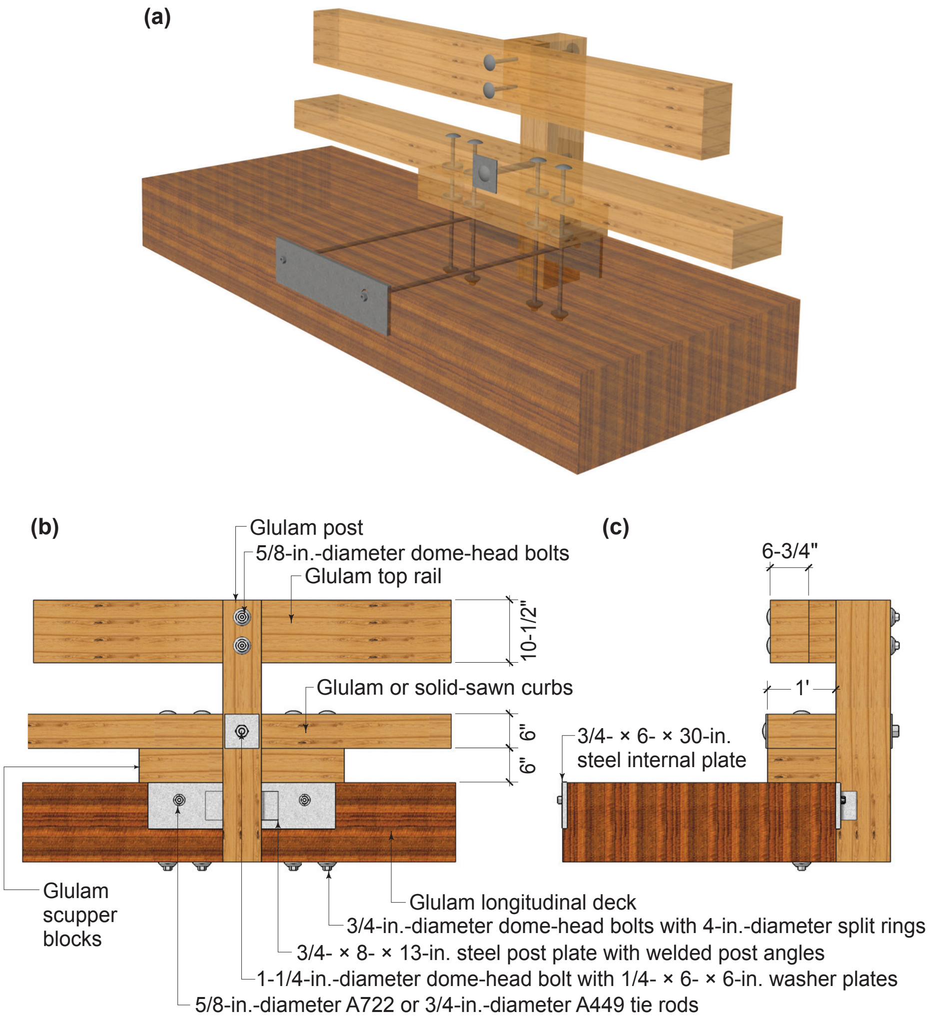


Figure 4.1. Glulam crash-tested railing option for longitudinal bridge decks meeting (NCHRP-350) test level 2 requirements: (a) perspective view; (b) outside profile view; (c) end view.

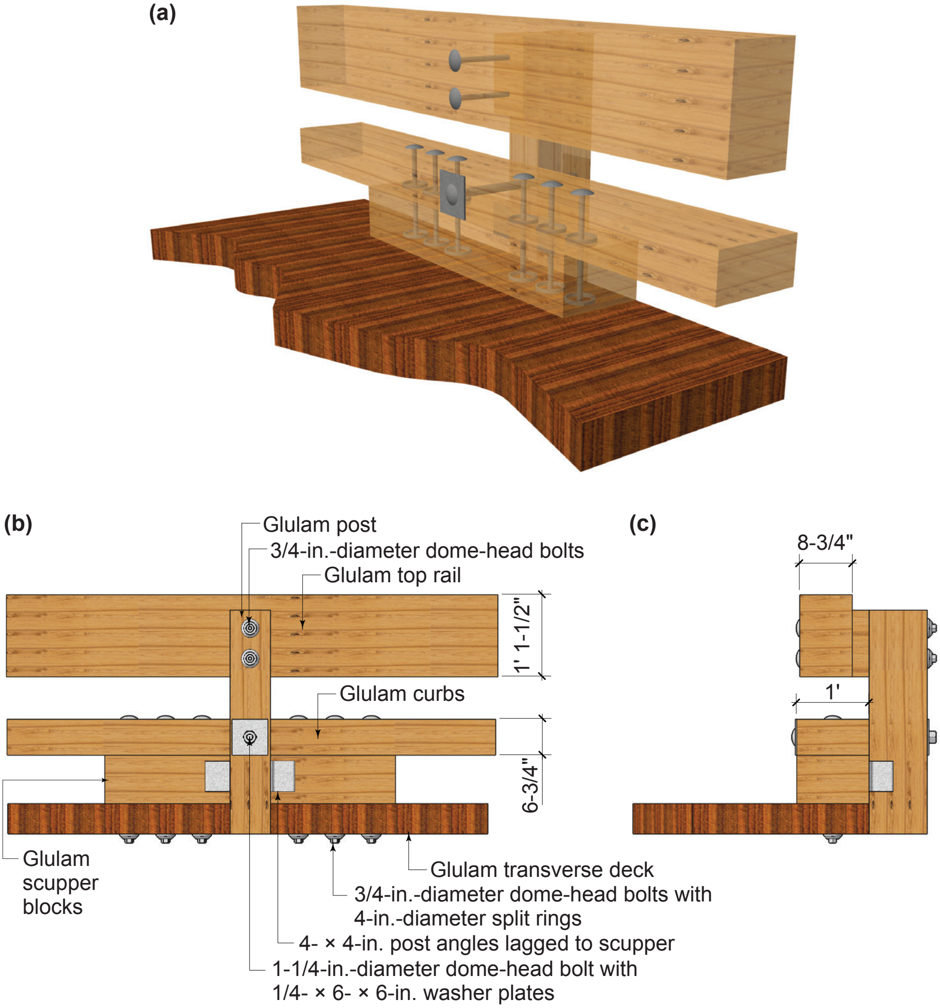


Figure 4.2. Glulam crash-tested railing option for transverse bridge decks meeting (NCHRP-350) test level 4 requirements: (a) perspective view; (b) outside profile view; (c) end view.

4.2 Asphalt Wearing Surface

Long-term serviceability of timber decks can be greatly increased by the proper application of a wearing surface. It is highly recommended that treated timber bridge decks receive some sort of wearing surface covering to protect them from the elements. The use of an asphalt wearing surface is most beneficial for bridges on unpaved, gravel roadways to decrease vehicle wear. Also, extending the asphalt pavement approximately 50 ft onto the roadway approaches is beneficial.

Proper application techniques favor the "sandwiching" of a waterproofing membrane between a base course and finish course of paving. Wrapping a membrane strip under the curbing provides an effective drip edge for any water runoff (Fig. 4.3).

Full documentation of applications and techniques is in the document "Guidelines for Design, Installation, and Maintenance of a Waterproof Wearing Surface for Timber Bridge Decks" (Weyers and others 2001).

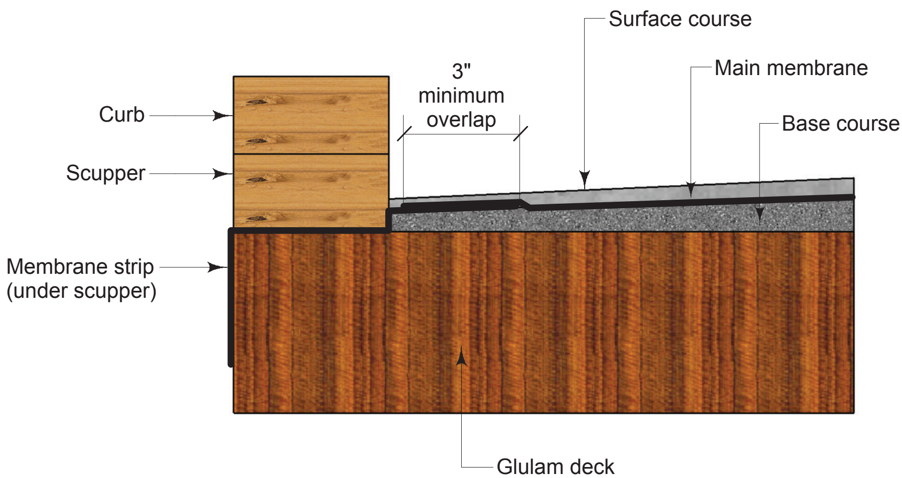


Figure 4.3. Membrane application for an asphalt wearing surface on glulam decks.

Chapter 5

Specifications and Design Considerations

5.1 Specifications

1. Standard for Glued-Laminated Timber Superstructures

This chapter contains a standard for production of glued-laminated wood used in the design and construction of bridge superstructures. It is intended to cover several types of glulam bridge superstructures and to augment, or support, design requirements that may be issued by the bridge owner.

2. Definitions and Abbreviations

Structural glued-laminated timber: An engineered stress-rated product of a timber laminating plant, comprised of wood laminations bonded together with adhesives. The grains of all laminations are approximately parallel longitudinally. See ANSI 117-2015 for a more detailed explanation (APA–The Engineered Wood Association 2015).

Glulam: Structural glued-laminated timber (wood)

AITC: American Institute of Timber Construction

APA/EWS: APA–The Engineered Wood Association

AWPA: American Wood Protection Association

AASHTO: American Association of State Highway and Transportation Officials

WWPI: Western Wood Preservers Institute

3. Qualifications of Fabricator

3.1 The glulam manufacturer must be a qualified licensee of AITC or APA/EWS.

3.2 All glued-laminated timber must be factory-fabricated (as far as practical). This includes cutting, drilling, and other fabrication as shown on shop drawings.

4. Codes and Standards

In addition to complying with all pertinent codes and regulations, material and installation procedures must comply with the following:

4.1 “Standard Specifications for Highway Bridges” (AASHTO 2002)

4.2 ANSI 190.1-2012 “American National Standard: Standard for Wood Products—Structural Glued Laminated Timber” (APA–The Engineered Wood Association 2013)

4.3 ANSI 117-2015 "Standard Specifications for Structural Glued Laminated Timber of Softwood Species"

4.4 "AWPA Book of Standards" (AWPA 2018a)

4.5 "Best Management Practices (BMP) for Preservative Treated Wood in Aquatic Environments" (WWPI 2012)

5. Certifications

5.1 Certifications required by the laminator: The laminator must provide an AITC or APA/EWS Certificate of Conformance to ANSI A190.1-2012.

5.2 Preservative treatment certification required (if applicable). A certificate of treatment must be furnished by a certified AWPA treating facility. The treating certification must list the identification of job, species of materials, type and retention of preservative provided, as well as the AWPA standard used as the guide for treating. In the event treated timber originates from more than one treating facility, certification must be furnished from each facility providing timber for this project.

6. Structural Design

The bridge must be designed in accordance with good engineering practices and in accordance with the standard specifications as adopted by AASHTO. The bridge design must be a glulam system comprised of either longitudinal decks, stringer systems, or transverse deck systems.

The structure must be designed for the following loads and dimensions:

Dead load (timber 50 lb/ft^3, wearing surface 140 lb/ft^3)

Live load (HL93)

Wet-stress design values must be used when applicable

Live load deflection (L/425)

Overall length of span (ft)

Overall roadway width (ft)

Skew (degrees)

7. Timber Materials

7.1 Lumber intended for glulam production must be visually or mechanically graded in conformance with the current edition of "AASHTO LRFD Bridge Design Specifications" (AASHTO 2017a) or with the current edition of "National Design Specifications for Wood Construction" (AF&PA 2015).

7.2 Glulam members must be finished to industrial appearance grade as per AITC 110-2001 (AITC 2001).

7.3 All lumber used in these standards must be either Douglas Fir–Larch or Southern Pine.

8. Preservative Treatment

All timber to be treated with the following oil-type preservatives in accordance with AASHTO material standards, M133 and M168, must conform to the AWPA use category system standards (AWPA 2018c):

8.1 Pentachlorophenol or copper naphthenate in Type A, heavy oil conforming to AWPA standard UC4B, and standards P35 and P36. Retention level must be 0.6 lb/ft^3.

8.2 Coal tar creosote conforming to AWPA standard UC4B and standard P1/P13. Retention level must be 12 lb/ft^3.

8.3 Incising is required for all Douglas Fir–Larch materials as per AWPA specifications.

8.4 Timber pedestrian deck, curb, and railings may be treated with the waterborne preservative CCA conforming to AWPA Use Category UC4B and standard P23 requirements or pentachlorophenol in Type C light oil conforming to AWPA Use Category UC4B and standard P35 with retention level of 0.3 lb/ft^3. Both treatments are recommended for use with southern yellow pine and must be specified for treatment prior to gluing.

8.5 All preservative treatments must be applied in accordance with "Best Management Practices (BMP) for Preservative Treated Wood in Aquatic Environments" (WWPI 2012).

8.6 AWPA Treatment Specifications

AWPA M2 Standard for the Inspection of Preservative Treated Products for Industrial Use

AWPA M4 Standard for the Care of Preservative-Treated Wood Products

AWPA P1/P13 Standard for Creosote Preservative

AWPA P1 Standard for Coal Tar Creosote for Land and Fresh Water and Marine (Coastal) Water Use

AWPA P23 Standard for Waterborne Preservative

AWPA P35 Standard for Oil-Borne Pentachlorophenol

AWPA P36 Standard for Oil-Borne Copper Naphthenate

9. Hardware

9.1 Fabricator must provide all connection steel and hardware for joining wood members to each other and to their supports, exclusive of anchors embedded in concrete.

9.2 All fasteners, except pre-stressing bars, must be galvanized (ASTM A123) mild steel (ASTM A307). Washers must be cast iron or malleable iron, timber type.

9.3 All steel plates and shapes must be galvanized (ASTM A153) mild steel (ASTM A36).

9.4 Aluminum deck brackets must be cast aluminum alloy 356.

9.5 “C” clips must be galvanized (ASTM A153) cast iron grade 30.

9.6 Prestressing bars and nuts for stress-laminated decks must be galvanized (ASTM A123) high-strength steel (ASTM A722) type II with an ultimate yield stress of 150 kips/in^2.

9.7 Hardware specification references:

“Standard Specifications for Transportation Materials and Methods of Sampling and Testing” (AASHTO 2011)

M111 Zinc (Hot-Dip Galvanized) Coatings for Iron and Steel Products

M232 Zinc Coating (Hot-Dip) on Iron and Steel Hardware

“ASTM Annual Book of Standards” (ASTM 2017)

ASTM A36 Standard Specification for Carbon Structural Steel

ASTM A722 Standard Specification for Uncoated, High-Strength Steel Bar for Prestressing Concrete

ASME B18.2.1 “Square and Hex Bolts and Screws (Inch Series)” (ASME 2012)

10. Bearing Pads

10.1 Fabricator must provide neoprene or elastomeric bearing pads in areas in which glulam girder or longitudinal decking material rests on steel or concrete abutments.Width must be sufficient to support bearing.

10.2 The durometer hardness must be between 50 and 70 and must have a minimum strength of 800 lb/in^2.

11. Material: Delivery, Storage, and Handling

11.1 Special care must be taken for all materials required for the project. Shipping, storage, and erection practices must be in accordance with industry standards.

5.2 Design Considerations

This publication was developed to comply with the “AASHTO LRFD Bridge Design Specifications” (ASHTO 2017a).

The information provided in this section indicates our assumptions and approaches, which are employed in the following calculation pages, and apply only to simple span superstructure configurations.

The presented material assumes the user has a basic knowledge of the AASHTO-LRFD design procedure.

Glulam superstructure types:

Longitudinal glulam decks

Stress-laminated glulam decks

Glulam stringer bridges

Transverse glulam decks

1. Design Loading

Design tables include the criteria of AASHTO HL93 loading criteria, which consists of the HS20 design truck plus a 640 lb per linear foot lane load. Dead load assumptions include 6-in. uniform depth asphalt wearing surfaces. Site-specific loading conditions, such as seismic- and substructure-bearing capacity loads, must be determined and analyzed by a registered professional engineer.

Dead load assumptions:

Treated timber: 50 lb/ft^3

Asphalt wearing surface: 140 lb/ft^3

Rail and curb system: 200 lb per linear foot

2. Deflection Criteria

AASHTO-LRFD recommends, but does not require, that a live load deflection limit of L/425 be used for timber bridge superstructures. This publication uses a live load deflection limit of L/425 for design purposes.

3. Tabulated Design Values

Tabulated design values are typically found in the AASHTO tables listed in AASHTO section 8.4. For glulam, additional combination layups and strengths may be found in ANSI 117-2015 “Standard Specifications for Structural Glued Laminated Timber of Softwood Species”.

To assist the designer, the appropriate modification factors are listed for each superstructure type.

Modification of tabulated design values:

For glulam stringer bridges and stress-laminated glulam deck systems,

C_M wet service factor

C_V volume factor or CL beam stability factor

C_λ time effect factor

C_{KF} format conversion factor

For longitudinal glulam deck and transverse glulam deck systems,

C_M wet service factor

C_{fu} flat use factor

C_λ time effect factor

C_{KF} format conversion factor

C_M Wet Service Factor (refer to AASHTO 8.4.4.3)
Applies to all glulam members and their allowable design values. AASHTO requires that timber bridge superstructures be designed for wet service conditions, unless dry service conditions are met. For glulam, dry service conditions are met when the maximum moisture content in service is less than 16%. Typically, dry service conditions only apply to glulam stringers in the glulam stringer bridge system and transverse stiffeners in the longitudinal glulam deck system.

C_V Volume Factor (refer to AASHTO 8.4.4.5)
Applies to glulam members when the load is applied perpendicular to the wide face of the laminations. This factor applies to flexure only. The volume factor C_V should only be applied if less than the beam stability factor C_L. The volume and beam stability factors should not be applied simultaneously.

C_λ Time Effect Factor (refer to AASHTO 8.4.4.9)
Applies to glulam members. This factor applies to flexure and shear design values in the strength I limit state.

C_{fu} Flat Use Factor (refer to AASHTO 8.4.4.6)
Applies to glulam members when the load is applied parallel to the wide face of the laminations. This factor applies to flexure only.

C_{KF} Format Conversion Factor (refer to AASHTO 8.4.4.2)
Applies to all glulam members and the applicable, allowable design values.

C_L Beam Stability Factor (refer to AASHTO 8.6.2)
Applies to glulam members when the load is applied perpendicular to the wide face of the laminations. This factor applies to flexure only. The beam stability factor C_L should only be applied if less than the volume factor, C_V. The beam stability and volume factors should not be applied simultaneously.

4. Slab Bridge Calculations (refer to AASHTO 4.6.2.3)

Longitudinal glulam decks and stress-laminated glulam decks are considered slab-type or integral wood designs by AASHTO. The design procedures are the same for both types with the exception that stiffeners are required for the longitudinal glulam deck system and stressing rods are required for the stress-laminated glulam deck systems.

All bridge criteria are entered into the calculations as well as a trial structure thickness and its appropriate allowable design values.

A calculated deck strip width is determined for the application of shear and live load moments.

For single lane widths,

$$E = 10.0 + 5\sqrt{L_1 W_1}$$

For multilane widths,

$$E = 84.0 + 1.44\sqrt{L_1 W_1} \leq \frac{12.0W}{N_L}$$

where

E is equivalent strip width (in.)

L_1 is the lesser of the actual span length or 60 ft

W_1 is the lesser of the actual bridge width or 60 ft for multiple-lane structures or the lesser of the actual bridge width or 30 ft for single-lane structures

W is actual edge–edge width of bridge (ft)

N_L is number of design lanes (ft)

Note: The calculation for the single lane width has taken into account the multiple presence factor.

5. Deflection Criteria (refer to AASHTO 2.5.2.6.2)

Live load deflection ratios for the longitudinal glulam deck and stress-laminated glulam deck designs are presented meeting the optional, minimum ratio of L/425.

The deflections are calculated as the larger of that resulting from the design truck alone or that resulting from 25% of the design truck in addition to the design lane load.

6. Stiffeners Longitudinal Glulam Deck Designs (refer to AASHTO 9.9.4.3)

Glulam stiffeners, with a minimum stiffness of 80,000 kip-in^2, are shown for the longitudinal glulam deck bridge systems. One is placed at bridge midspan, and the remaining stiffeners are evenly spaced at no greater than 8-ft centers.

7. Post-Tensioning Stress-Laminated Glulam Deck Designs (refer to AASHTO 9.9.5.6.3)

High-strength, 1-in.-diameter, 150-kips/in^2 ultimate tensile strength bars are used for the post-tensioning system. Maximum spacing of bars must be no greater than 48 in. on center; however, spacings are generally dictated by guide rail post spacings and by achieving a symmetrical staggered layout without interference between guide rail posts and bar anchorages. Experience has shown that excessive crushing of the timber occurs under the loaded stressing plates. A factor of 0.8 has been multiplied with the allowable compressive stress of the deck, beyond any other reduction factors, to assist in minimizing this condition.

8. Camber Stress-Laminated Glulam Deck Designs (refer to AASHTO 8.12.3)

A positive camber, equal to three times the dead load deflection, is calculated into simple span, glulam stringers.

9. Glulam Stringer Bridge Calculations

In designing the glulam stringer bridge, all bridge criteria are entered into the calculations as well as a trial stringer size, species, and appropriate allowable design values.

The calculations are prepared in such a way that the interior stringers are checked first, against the trial size, and then the exterior stringers are checked. If any of the design elements fail, a different size stringer would be required.

10. Distribution Factors

Other than slightly different loading conditions, the main difference between the interior and exterior stringer design process is in the distribution factors.

11. Interior Stringers (refer to AASHTO 4.6.2.2.1-1)

The distribution factor equals the stinger spacing (ft) divided by 10 (ft). The multiple presence factor has been included in this calculation.

12. Exterior Stringers (refer to AASHTO 4.6.2.2.2d, AASHTO 4.6.2.2.2d-1)

The distribution factor for exterior stingers is taken to be the least of the following:

- Lever rule
- Rigid body rotation
- One lane loaded with multiple presence factor
- Two lanes loaded with multiple presence factor

13. Deflection Glulam Stringer Bridge Designs (refer to AASHTO 2.5.2.6.2, AASHTO 3.6.1.3.2)

Live load deflection ratio for the glulam stringer bridge designs are presented meeting the optional, minimum ratio of $L/425$.

The deflections are calculated as the larger of that resulting from the design truck alone or that resulting from 25% of the design truck in addition to the design lane load.

14. Camber Glulam Stringer Bridge Designs (refer to AASHTO 8.12.1)

A positive camber, equal to two times the dead load deflection is calculated into simple span, glulam stringers.

15. Transverse Glulam Deck Calculations

In designing the transverse glulam deck, all bridge criteria is entered into the calculations as well as a trial deck thickness, species, and appropriate allowable design values. An assumed width of panel is also entered.

16. Width of Panel for Design

A panel width is determined for the application of loads by the following:

- Two times panel thickness plus 40 in.
- (Noninterconnected panel designs) AASHTO 4.6.2.1.3
- Four times panel thickness plus 30 in.
- (Interconnected panel designs) AASHTO 4.6.2.1.3

17. Truck Loading

These calculations are written as simple span designs.

Live loading for moments is calculated by placing the vehicle tire at midspan, between supporting stringers.

Live loading for shear is calculated by placing the vehicle tire at a distance equal to the panel thickness from the support.

18. Deflection Transverse Glulam Deck Designs (refer to AASHTO 2.5.2.6.2, AASHTO 3.6.1.3.2)

Live load deflection ratio for the transverse glulam deck designs are presented meeting the optional, minimum ratio of *L*/425.

The deflections are calculated as the larger of that resulting from the design truck alone or that resulting from 25% of the design truck in addition to the design lane load.

In conjunction, these calculations account for an asphalt wearing surface that limits the live load deflection along the panel interface joints to 0.1 in.

References

AASHTO. 2002. Standard specifications for highway bridges. 17th ed. Washington, DC: American Association of State and Highway Transportation Officials.

AASHTO. 2017a. AASHTO LRFD bridge design specifications, 8th edition, U.S. customary units, with 2018 interim revisions. Washington, DC: American Association of State and Highway Transportation Officials. 2,160 p.

AASHTO. 2017b. Standard specifications for transportation materials and methods of sampling and testing. Washington, DC: American Association of State and Highway Transportation Officials.

M111 Zinc (Hot-Dip Galvanized) Coatings for Iron and Steel Products

M232 Zinc Coating (Hot-Dip) on Iron and Steel Hardware

AASHTO Material Standards:

M133 Standard Specification for Preservatives and Pressure Treatment Processes for Timber

M168 Standard Specifications for Wood Products

M275 Standard Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete

AASHTO. 2018. http://www.transportation.org. Washington, DC: American Association of State Highway and Transportation Officials (Feb. 26, 2018).

AF&PA. 2015. National design specifications for wood construction–ASD/LRFD. Washington, DC: American Forest & Paper Association. 341 p.

AITC. 2018. http://www.aitc-glulam.org. Centennial, CO: The American Institute of Timber Construction (Feb. 26, 2018).

AITC. 2001. AITC 110-2001. Standard appearance grades for structural glued laminated timber. http://www.aitc-glulam.org. Englewood, CO: American Institute of Timber Construction.

APA–The Engineered Wood Association. 2013. ANSI 190.1-2012. American national standard: standard for wood products — structural glued laminated timber. Tacoma, WA: APA–The Engineered Wood Association. 40 p.

APA–The Engineered Wood Association. 2015. ANSI 117-2015. Standard specification for structural glued laminated timber of softwood species. Tacoma, Washington: APA–The Engineered Wood Association.

ASME. 2012. ASME B18.2.1 Square and hex bolts and screws (inch series). New York: American Society of Mechanical Engineers; Washington, DC: American National Standards Institute.

ASTM. 2017. Annual book of standards. West Conshohocken, PA: American Society for Testing and Materials International.

A36 Standard Specification for Carbon Structural Steel

A123 Standard Specification for Zinc (Hot-Dip Galvanized) coatings on iron and Steel Products

A153 Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A307 Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod of 60 000 PSI Tensile Strength

A722 Standard Specification for Uncoated, High-Strength Steel Bar for Prestressing Concrete

AWPA. 2018a. AWPA book of standards. Birmingham, AL: American Wood Protection Association.

AWPA Treatment Specification References:

M2 Standard for the Inspection of Preservative Treated Products for Industrial Use

M4 Standard for the Care of Preservative-Treated Wood Products

P1/P13 Standard for Creosote Preservative

P1 Standard for Coal Tar Creosote for Land and Fresh Water and Marine (Coastal) Water Use

P5 Standard for Waterborne Preservative

P8 Standard for Oil-Borne Preservatives

P9 Standard for Solvents and Formulations for Organic Preservative Systems

AWPA. 2018b. http://www.awpa.com. Birmingham, AL: American Wood Protection Association (Feb. 26, 2018).

AWPA. 2018c. U1. Use category system: user specification for treated wood. Birmingham, AL: American Wood Protection Association.

Faller, R.K.; Ritter, M.A.; Rosson, B.T.; Fowler, M.D.; Duwadi, S.R. 2000. Two test level 4 bridge railing and transition systems for transverse timber deck bridges. Transportation Research Record 1696. Paper No. 5B0110. Washington, DC: National Academy Press. http://www.fpl.fs.fed.us/documnts/pdf2000/falle00a.pdf.

Ritter, M.A.; Faller, R.K.; Bunnell, S.; Lee, P.D. Hilbrich; Rosson, B.T. 1998a. Plans for crash-tested bridge railings for longitudinal wood decks on low-volume roads. Gen. Tech. Rep. FPL–GTR–107. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 12 p. http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr107/fplgtr107.pdf.

Ritter, M.A.; Faller, R.K.; Lee, P.D. Hilbrich; Rosson, B.T.; Duwadi, S.R. 1998b. Plans for crash-tested wood bridge railings for concrete decks. Gen. Tech. Rep.

FPL–GTR–108. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 18 p. http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr108/fplgtr108.pdf.

Ritter, M.; Lee, P. 1996. Recommended construction practices for stress-laminated wood bridge decks. In: Proceedings of the International Wood Engineering Conference. Vol. 1. Baton Rouge, LA: Civil/Environmental E. Louisiana State University. 237–244. https://www.fpl.fs.fed.us/documnts/pdf1996/ritte96c.pdf.

Wacker, J.P.; Smith, S. 2001. Standard plans for timber bridge superstructures. Gen. Tech. Rep. FPL–GTR–125. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 53 p. http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr125.pdf.

Weyers, R.E.; Loferski, J.R.; Dolan, J.; Hramis, D.; Howard, J.E.; Hislop, L. 2001. Guidelines for design, installation, and maintenance of a waterproof wearing surface for timber bridge decks. Gen. Tech. Rep. FPL–GTR–123. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 15 p. https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr123.pdf.

WWPI. 2012. Best management practices (BMP) for preservative treated wood in aquatic environments. Vancouver, WA: Western Wood Preservers Institute. https://preservedwood.org/portals/0/documents/BMP.pdf.