Designing Timber Highway Bridge Superstructures Using AASHTO–LRFD Specifications

Authors:

James P. Wacker, Forest Products Laboratory, U.S. Forest Service,
Madison, WI, jwacker@fs.fed.us
James S. Groenier, Missoula Technology and Development Center, U.S. Forest Service,
Missoula, MT, jgroenier@fs.fed.us

ABSTRACT

The allowable-stress design methodology that has been used for decades to design timber bridge superstructures is being replaced in the near future. Beginning in October 2007, bridge designers will be required by the Federal Highway Administration (FHWA) to utilize the Load and Resistance Factor Design (LRFD) design specifications published by the American Association of State Transportation and Highway Officials (AASHTO). Until recently, significant discrepancies existed between the two design methodologies as they pertain to the design of timber bridges. However, several modifications and improvements to the LRFD bridge design specifications were recently incorporated into the latest edition of the LRFD bridge design standards in an effort to mimic allowable-stress design techniques using current timber design standards. Timber bridge supstructures designed using the latest LRFD design requirements will still not be identical to those designed with allowable-stress design procedures, primarily due to new requirements for higher design vehicle live-loads and modified live-load distribution equations within AASHTO–LRFD design specifications. In addition, timber bridges designed using allowable-stress design methods prior to 2007 will be not be required to use AASHTO–LRFD methods for load rating purposes.

INTRODUCTION

The specifications which serves as the basis for design of timber bridge superstructures was significantly changed for the first time in several years. The last significant changes to specifications for timber bridges was in the 1992 version of AASHTO–Allowable Stress Design (ASD) [1] when it adopted hardwood design values, introduced the volume-effect modification factor for glulam beams, and set a recommended limitation for live load deflection at 1/500th of the span length. These AASHTO design standards referenced the National Design Specification for Wood Construction [2].

The recent changes involve the transition from the traditional allowable-stress-design (ASD) to the recently developed load and resistance factor design (LRFD) methodology. The Federal Highway Administration (FHWA) recently set the horizon date of October 2007 for the 2002 edition AASHTO-ASD bridge design specifications [3] to become obsolete, with no plans to update them in the future. After this date, bridge designers will be required to design timber bridge superstructures in accordance with the latest version of AASHTO–LRFD bridge design specifications. Engineers and designers need to become familiar with the newest version of the AASHTO-LRFD bridge design specifications [4] in order to successfully design timber bridge superstructures that meet the requirements set by these national design standards.

This paper will summarize the recent changes and refinements that are included in the current AASHTO–LRFD Bridge Design Specifications (4th edition). In addition, it will present results from a glulam girder bridge design comparison that demonstrates how bridge girders similar in size were designated when using the different design specifications.

BACKGROUND

LRFD bridge design specifications were initially published by AASHTO in 1994, with initial efforts focused on developing appropriate initial values for the LRFD design specification for timber bridges [5]. These initial values included load factors, nominal resistance values, and resistance factors for design of timber bridge superstructures.

Early indications of the transition to the LRFD design format were evident in the late 1990's, as several state transportation departments started utilizing the AASHTO–LRFR when advantageous for load rating their timber bridge superstructures. Their design engineers began to inquire about the technical basis for various differences between the two design methods. Several aspects of the design and load rating process using AASHTO-LRFD were clearly in need of closer examination.

However, the real alarm was sounded when the Federal Highway Administration set the transition deadline for October 2007. In response, the ASCE timber bridge technical committee began to closely examine the two design standards beginning in 2005, as they pertain to timber highway bridges, in preparation for the approaching transition to LRFD design format.

An analysis paper reported in 2005 focused on comparing ASD and LRFD for load rating purposes [6]. This analysis work discovered large differences between load rating using the two design methods for an 18-foot-long, sawn lumber stringer bridge with transverse plank decking. Not only were live-load design levels increased with LRFR, but the load distribution criteria for plank decks were different also. More importantly, this comparative analysis identified several discrepancies in the LRFR that partly contributed to the load rating differences. These included the dynamic load (or impact) factor, format conversion factors, and modifications to baseline design values (i.e., load duration, or time effects, and moisture condition)

When these discrepancies for load rating timber bridges were shared with practicing engineers and industry groups later in 2005, a task group comprised of government and industry representatives was formed to resolve the discrepancies. As a result, the help of the American Institute of Timber Construction (AITC) was enlisted in developing proposed changes to the AASHTO–LRFD bridge design specifications. Proposed modifications to the 3rd edition of the AASHTO-LRFD specifications for timber bridges were then presented to the AASHTO T-16 technical committee in summer 2005.

An analysis paper reported in 2006 again focused on comparing ASD and LRFD for load rating purposes [7]. This analysis work reaffirmed the large discrepancies between the two design methods when load rating a 48-foot-long, glulam girder with transverse glulam deck bridge. It also determined that the conversion factor of 2.16 listed in AASHTO–LRFD (3rd edition) is invalid for timber bridge superstructure design. Instead, a conversion factor of 2.5 was proposed for AASHTO–LRFD (4th edition) to more accurately reflect a 10 to 1 live-load to dead-load ratio typical of superstructure design for timber highway bridges along with its revised load factor equation.

Lastly, the full AASHTO Committee on Bridges and Structures approved these modifications in summer 2006 for inclusion in the 4th edition of AASHTO-LRFD bridges specifications.

MODIFICATIONS TO AASHTO–LRFD BRIDGE DESIGN SPECIFICATIONS

Several changes have been made to Section 8 (wood structures) of the new 4th edition of the AASHTO–LRFD Bridge Design Specifications. Most of the significant changes are summarized in the following three categories:

Ease Transition to LRFD Design Format

Several modifications were made to in an effort to make the new standards resemble the format of the latest AASHTO–ASD standard specifications:

- **Definition of terminology:** many of the notations were renamed in order to resemble the 2005 NDS and remain familiar to the design engineer. For example, 'reference design value' is used instead of 'base resistance'.
- **Design values are depicted as in 2005 NDS:** the previous tables for 'Base Resistance Values' have been replaced with reference design values very similar to the design value tables in 2005 NDS.
- **Adjustment factors instead of resistance factors:** these condition-of-use factors are defined in a familiar manner, such as C_M, C_D, etc.
- **Time effects factor**: The time effects factor was modified so that it reflected different values for corresponding strength limit states, instead of applying a factor of 0.8 to all limit states.

Eliminate Inconsistencies with ASD Design Format

Several modifications were made in an effort to remove the inconsistencies with the AASHTO–ASD standard specifications and the 2005 NDS:

- **New conversion factor:** A new conversion factor of 2.5 is introduced for most aspects of timber bridges. The only exception is compression perpendicular-to-grain, which has a conversion factor of 2.1.
- **Size Factor:** This factor is now identical in its definition and applicability as in the 2005 NDS or 2002 AASHTO–ASD design specifications.

Intended Changes to Various Design Parameters

A few modifications were intentionally made in order to modify certain design parameters:

- **Load distribution for girder bridges:** there have been some changes to way transverse decks distribute live load to underlying girders for plank decks, nail-laminated decks, and stress-laminated decks.
- **New connection design criteria:** new requirements for connection design have been added in Section 8.13 in accordance with 2005 NDS.
- **Live load deflection criteria:** Although there is no change in the calculation method, the live load limitation is now Span/425 in LRFD versus Span/500 in the ASD specifications.

CASE STUDY: DESIGN OF A GLULAM GIRDER BRIDGE

This design example is based upon the design example 'longitudinal stringer with transverse deck' in Glued Laminated Timber Bridges Systems Manual [8] published by AITC.

The glulam timber bridge had the following conditions:

- Type: longitudinal glulam stringer
- Deck: transverse glulam panels
- Girders: 24F-V4
- Span length: 15.04m (49ft 4-in.)
- Roadway Width: 10.36m (34ft)

Several MathCAD design worksheets were developed to complete the superstructure designs using various live load criteria and AASHTO–LRFD (4th edition) bridge design specifications. Table 1 shows the 'required interior girder size' when using various AASHTO live load vehicles. This demonstrates that the higher load requirements of the HL-93 live load produces about 25 percent higher resistance values as compared to HS20-44, which makes it nearly equivalent to the AASHTO HS25-44 live load effect.

	Allowable Stress Design (ASD)		Load Resistance and Factor Design (LRFD)
AASHTO Live load criteria	HS20-44 Vehicle	HS25-44 Vehicle	HL-93 Vehicle
Required Interior Beam Size (in.)	10-3/4 x 42	10-3/4 x 46-1/2	10-3/4 x 45

TABLE 1 - REQUIRED GIRDER SIZE FOR LRFD VERSUS ASD USING VARIOUS DESIGN LIVE LOAD CRITERIA.

SUMMARY

Several modifications and improvements to the LRFD bridge design specifications were recently incorporated into the latest edition of the LRFD bridge design standards in an effort to mimic allowable-stress design (ASD) specifications utilizing current timber design standards [9]. However, timber bridge supstructures designed using the latest AASHTO–LRFD (4th edition) bridge design specifications will still not be identical to those designed with allowable-stress design procedures, primarily due to higher design vehicle live-load requirements and modified live-load distribution equations. The higher LRFD design loads generated by HL-93 live load criteria are nearly equivalent to HS25-44 live load criteria designated by the ASD specifications. In addition, live load deflection criteria is set at span/425 for LRFD, which is slightly less stringent than span/500 for ASD. Lastly, timber bridges that were initially designed using ASD methods prior to this transition will be not be required to use AASHTO–LRFR [10] for load rating purposes.

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