Investigation of Glulam Girder Bridges Constructed Prior to 1970

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Summary

The United States glulam industry began requiring high-quality, tension grade laminations in 1970 for the manufacture of beams designed primarily for bending applications. Glulam girders that were manufactured prior to that date, and remain in-service today, are currently subject to significant strength reductions during the bridge load rating process. This paper describes this issue as it pertains to an inventory of early glulam girder bridges, built primarily by the USDA Forest Service between the years 1950-70, on their roadway network. It describes a series of field bridge evaluations, a laboratory investigation of salvaged girders, and discusses the development of an alternative approach for load rating these unique timber bridges. The overall goal of these efforts was to preserve these early glulam girder bridges that are in danger of replacement even though they carried heavy logging trucks safely for decades, and in many cases, are still performing satisfactorily.

Keywords: tension grade, laminations, glulam, bridge, girder, load rating, strength reduction

1. Introduction

Historically, the U.S. Forest Service (FS) has used timber components in the construction of many of their highway bridges. There are approximately 4,100 bridges currently in-service on the National Forest transportation network that employs timber as primary bridge components. A large proportion of these bridges are comprised of glulam (glued laminated timber) materials that are manufactured using dimension lumber and structural "wet-use" adhesives. The current load rating process (AASHTO 2012) for glulam girder bridges contains significant changes that present new challenges to bridge engineers who must routinely assign safe load carrying capacities for bridges on public roadways.

A subset of these FS glulam girder bridges were manufactured prior to 1970, when the American

Institute of Timber Construction (AITC) first introduced a national standard for tension lamination quality. Without the specially-graded tension laminations, bending design values used for load rating are now required to be reduced by approximately 15% for beams 38 cm (15 in.) deep or less, and 25% for beams deeper than 38 cm (15 in.) (ASTM D3737). This translates into many of these structures having to be posted for reduced live load and slated for replacement, despite their satisfactory condition after 40-50 years in-service. The average replacement cost is estimated at more than $300,000 for structure, with several needing immediate replacement due to their vital service towards forest fire suppression efforts. As a result, further investigations were warranted before investing in significant bridge replacement costs. A field investigation of these bridges would verify their in-service performance and directly assess their load carrying capacity. A laboratory investigation of salvaged glulam beams would yield data on their ultimate bending strength values. The combined results would provide the basis for development of a new load rating strategy for assigning a safe and reliable load capacity to these bridges into the future.

A recent technical article by Powell 2004 spoke about the implications of this strength reduction for glulam beams in U.S. warehouse buildings constructed before 1970. A few years later the American Institute of Timber Construction released AITC Technical Note 26 (AITC 2007) for practicing engineers which provided more details about the strength reduction, but added some confusion for engineers. This reduction factor was initially thought to be duplicative with the glulam volume factor which was introduced beginning in 1991, and also presents a significant reduction for large glulam stringers (Moody and Others 1990). It was subsequently determined that both the volume factor and the pre-1970 strength reductions both apply to these early glulam stringers for load rating purposes.

The load rating of bridges in the United States is guided primarily by the American Association of State Highway and Transportation Officials (AASHTO). The Manual for Bridge Evaluation, AASHTO 2012 and AASHTO LRFD Bridge Design Specifications 2013, contain limited guidance for timber bridge ratings, but allow for diagnostic load testing to be performed as an alternative means of determining load capacity.

2. Objective

The primary objectives of this project were: 1) Conduct field investigations of remaining pre-1970 glulam girder bridges including live load testing; 2) Perform laboratory evaluations on glulam bridge girders salvaged from an Alaskan bridge; 3) Develop an alternative load rating strategy specifically for these older glulam bridges. The overall goal is to preserve these early glulam bridge structures that are being load restricted and slated for replacement, despite the fact they have been carrying logging trucks safely for decades and still performing satisfactorily in many cases.

3. Field Investigations

Two groups of glulam girder bridges were investigated in the states of Oregon and Washington during the 2009 and 2010 summer seasons. Static live load testing was conducted at all field bridges. Two different load cases were evaluated for each bridge. Load case 1 had the truck straddling the roadway centreline while its centroid was positioned at midspan. Load case 2 had the truck shifted laterally so that the wheel line was 0.6 m from the curb face. In all cases, data was collected before and after loading to detect residual movements. Supports were also checked to ensure there was no settlement under loading. Midspan deflections were collected with Celesco string potentiometers attached to the bottom side of the beams (Figure 1). Strain measurements were collected with transducers manufactured by Bridge Diagnostics Inc. Strain transducers were mounted on each girder at the midspan-bottom tension zone and at the intermediate support- topside tension zone. The data collection was automatically captured with a Campbell-Scientific CR-10 datalogger unit. In addition, suspended rulers and an optical level were used to collect midspan static deflections of the glulam girders (Figure 2)

In order to learn more about the quality of the tension laminations in these glulam girder bridges, an extensive field investigation was conducted at several field bridges. Core samples were removed to determine the wood species via microscopic analysis. Glue-joints and knot locations in the tension zones of the glulam girders was also recorded. Non-destructive testing was also performed to learn more about the internal integrity of the tension laminations at three bridges. Stress wave timing measurements were collected in two different orientations in the tension zone laminations using a stress wave timer. The stress wave parallel-to-grain data was collected to correlate with stiffness values in the tension zone laminations. While the perpendicular-to-grain data were used to detect internal decay pockets. Resistance micro-drilling measurements were also taken at various locations in the tension laminations in order to gain a better understanding of their growth ring orientation and grade characteristics.

Figure 1. Live load testing data was collected via string potentiometers (deflection) and transducers (strain).

Figure 2. Optical level was also used to collect deflections from calibrated rules suspended from each girder.

4. Laboratory Evaluations

After the 15.2m (50 ft) long glulam girders were removed from service at the Jenny Creek bridge site near Kake, Alaska (Figure 3), they were transported to the Forest Products Laboratory in Madison, Wisconsin. Several laboratory investigations were conducted in order to reliably determine the residual capacity of these early glulam bridge girders. Visual defects were physically mapped, in addition to extensive scanning using stress wave timing device in a perpendicular to grain orientation (Figure 4). Static load testing was conducted (Figure 5) using 4-point bending arrangement in order to produce a uniform bending moment through the midspan section of the bridge girders. Testing was first completed to measure the modulus of elasticity of each beam. Then loading to ultimate failure was performed over a 10-minute load duration target period.

Figure 3. Pre-1970 glulam girders salvaged from site in Alaska.

Figure 4. NDE testing is performed in the laboratory to detect internal decay.

Figure 5. Static load testing was performed to determine member stiffness and ultimate load capacity of these 60-year-old salvaged glulam girders at the FPL Centennial Research Facility.

Testing results of four members showed that these pre-1970 manufactured glulam bridge girders had an average modulus of elasticity of 11,652 MPa (1.69 X 10^6 lb/in.^{2}) and failed at an average applied loading of 645 kN (145 Kips). These values are significantly higher than the original design stress level and suggest that the strength reduction factors may be overly conservative in some cases.

5. Modified Load Rating Approach

A modified load rating approach is currently being developed with several key components. A detailed on-site inspection will be a vital component of the new approach. Documentation of the type of finger joints utilized and the quality of the tension laminations will be very important. NDE tools will be employed to detect any internal decay or deterioration not obvious by visual assessment. It most likely will include an assessment of its live load performance under design loads. This general approach should allow the engineer to confidently assign a more accurate load rating than the existing bridge rating guides permit.

6. Summary and Conclusions

An extensive investigation was conducted in the field and laboratory settings to address a categorical strength reduction factor for glulam girders manufactured prior to 1970 in the US. These efforts demonstrated that a sampling of these bridges in the states of Oregon, Washington, and Alaska appear to be in satisfactory condition and capable to carry full design loads. A modified load rating approach is currently under development which could be applied to these unique structures reliably into the future.

7. References

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