LIVE LOAD TESTING AND LOAD RATING OF OLDER GLULAM GIRDER BRIDGES

James P. Wacker¹, James Scott Groenier², Lola E. Hislop³, David Strahl⁴, Bill Salsig⁵

ABSTRACT: This poster paper is focused on the field performance of glulam girder bridges built prior to 1970 in the Pacific-Northwest Region of the United States. Although many of these bridges are still performing satisfactorily and recent inspections have not detected any significant structural problems, new reductions in the load rating process are significant. The reductions associated with these pre-1970 glulam bridges are based on the beams not having the higher-quality tension laminations found in modern glulam beams. Due to the absence of these specially-graded tension laminations, research studies suggest that these glulam beams have lower strength values and require engineers to reduce their bending resistance values by up to 25 percent. The aim of this field investigation was to develop a modified approach to load rating pre-1970 glulam bridges that results in less severe reductions than required in the current load rating procedure. This poster reports on the recent field testing conducted at several bridges in State of Oregon during August, 2009. Field testing involved physical mapping, non-destructive testing, and core sampling of girder laminations in those zones loaded in tension. In addition, girder deflection and strain measurements were recorded under static live loading.

KEYWORDS: Glued-laminated timber, wood, bridge, tension laminations, live load, deflection, strain

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 employ timber as primary structural components (i.e., decks, girders, slabs). 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 2008) for glulam girder bridges contains significant changes that present new challenges to bridge engineers who must assign safe load carrying capacities.

This particular subset of glulam girder bridges were manufactured prior to 1970, when the American Institute of Timber Construction (AITC) first introduced a national standard for tension laminations, when the American Institute of Timber Construction (AITC) first introduced a national standard for tension laminations, bending design values used for load rating are now required to be reduced by approximately 15% for beams 15 inches deep or less, and 25% for beams deeper than 15 inches. This translates to many of these structures having to be posted for reduced live load capacity. Despite their good condition (based on the latest NBI condition rating) after 40-50 years in-service, any structures posted for less than highway legal loading are then considered to be structurally deficient, making them candidates for replacement. The average replacement cost is estimated at $300,000 for these older glulam bridges, with several bridges needing immediate replacement due to their vital service towards forest fire suppression. A field investigation was needed to verify that in-service glulam bridge girders manufactured prior to 1970 are still performing satisfactorily under design live loads. This will allow a new load rating strategy to be drafted which should provide engineers with increased confidence in assigning a safe load capacity to these bridges into the future.

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The goal of this study was to gain a better understanding about the field performance of glulam girder bridges that were designed and manufactured prior to 1970. The results of this study will result in a modified load rating procedure which includes engineering guidance for field testing requirements.

2 OBJECTIVE AND SCOPE

The overall objective of this study is to determine if the structural performance of existing glulam girder bridges manufactured before 1970 (i.e., do not contain tension-grade laminations) remains adequate, despite strength reduction adjustment factors for load rating. This poster paper will report on the recent field investigations conducted at several bridge sites in southern Oregon during August 2009. Field testing involved physical mapping, non-destructive testing, and core sampling of girder laminations in those zones loaded in tension. In addition, girder deflection and strain measurements were recorded under static live loading.

3 BACKGROUND

3.1 ASTM STANDARD D3737

The strength reduction factor for glulam beams manufactured prior to 1970 is outlined ASTM Standard D3737 (ASTM 2008). For beams less than 15 inches (38 cm) deep, the reduction in allowable bending stress is 15 percent. And for beams greater than 15 inches deep, the reduction in allowable bending stress is 25 percent. Laboratory studies performed by FPL in the 1970’s focused on tension lamination quality in glulam beams (Bohannon & Moody, 1969; Marx & Moody 1981) and formed the basis for this ASTM D3737 strength reduction factor for older glulam beams.

3.2 AITC TECHNICAL NOTES

A recent technical article by Powell 2004 [3] 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. This advisory provided more details about the reasoning behind the strength reduction but added some confusion for engineers. This reduction factor was initially thought to be duplicative with the volume factor, C_v, which was first adopted by NDS in 1991 and also requires a significant reduction for large glulam beams (Moody and Others 1990) [6]. It was subsequently determined that for load rating purposes, both the volume factor and the pre-1970 strength reductions applied.

3.3 AASHTO BRIDGE LOAD RATING

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 2008 and AASHTO LRFD Bridge Design Specifications, 4th Ed., 2007, contains limited information for timber bridges. However, it currently does not include or reference the ASTM D3737 strength reduction for old glulam beams. Until this strength reduction factor for glulam beams manufactured prior to 1970 is adopted by AASHTO, prudent engineers must apply the strength reduction. However, AASHTO also provides guidance on performing diagnostic load testing to support load rating exercises. That is the approach used in this study.

4 FIELD TESTING

4.1 BRIDGE DESCRIPTIONS

Seven pre-1970 glulam girder bridges were evaluated in-service during August 2009 and are described in Table 1. Two of the seven bridges are shown in Figure 1 (Dairy Creek) and Figure 2 (Fishhole No.2). The glulam girders were all 28 cm wide but varied in depth from 53 to 109 cm. Nearly all bridge decks were continuously nail-laminated, however, the Upper Williamson Bridge was recently renovated with a transverse glulam panel deck. These glulam girder bridges are unique in that many of them were designed with end sections cantilevered beyond the abutments from 2 to 3m. The intent of this cantilevered approach was to reduce overall beam depth, however, the design has been problematic as the cantilever end deflection and lack of retaining structure at the bridge ends has led to backfill erosion near the end of most of these bridges.

<table>
<thead>
<tr>
<th>Bridge name</th>
<th>Span type</th>
<th>Span (m)</th>
<th>Girder depth (cm)</th>
<th>Deck depth (cm)</th>
<th>Girder size (cm)</th>
<th>Deck type</th>
<th>Span size (cm)</th>
</tr>
</thead>
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<tr>
<td>Upper Williamson</td>
<td>simple</td>
<td>16.0</td>
<td>28 x 109</td>
<td>17</td>
<td>glulam</td>
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<td>28 x 96</td>
<td>15</td>
<td>nailed</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.0m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>one end</td>
<td>14.0</td>
<td>28 x 91</td>
<td>19</td>
<td>nailed</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.0m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy Creek</td>
<td>one end</td>
<td>12.8</td>
<td>28 x 87</td>
<td>19</td>
<td>nailed</td>
<td>30</td>
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<td></td>
<td>2.8m</td>
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<td></td>
</tr>
<tr>
<td>Sycan Marsh</td>
<td>simple</td>
<td>21.4</td>
<td>28 x 128</td>
<td>15</td>
<td>nailed</td>
<td>0</td>
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</tr>
<tr>
<td>Fishhole no.1</td>
<td>both ends</td>
<td>7.3</td>
<td>28 x 53</td>
<td>13</td>
<td>nailed</td>
<td>25</td>
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<td></td>
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</tr>
<tr>
<td>Fishhole no.2</td>
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<td>13</td>
<td>nailed</td>
<td>30</td>
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</table>

a—several spans were cantilevered one or both ends.

Figure 1: Dairy Creek glulam girder bridge located on the Fremont-Winema National Forest near Paisley, Oregon.
4.2 INVESTIGATION OF TENSION-ZONE LAMINATIONS

In an effort to learn more about the quality of the tension laminations in these glulam girder bridges, an extensive field investigation was conducted at three of the more accessible 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 were also recorded.

Non-destructive testing was 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 Metriguard 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 was 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 the growth ring density and grain orientation.

4.3 LIVE LOAD TESTING

Static live load testing was conducted at all seven bridges. For each cantilevered bridge, the main span and the cantilever end section were tested while the truck was positioned for maximum deflection. A photograph of the test truck is shown in Figure 3, and a description of the truck axles and loading configuration for each bridge is in Table 2. Two different load cases were evaluated for each bridge. Load case 1 had the truck straddling the roadway centerline 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.

![Figure 2: Fishhole No.2 glulam girder bridge located on the Fremont-Winema National Forest near Bly, Oregon.](image)

![Figure 3: Live load test vehicle used at all glulam girder bridges](image)

<table>
<thead>
<tr>
<th>Bridge name</th>
<th>Truck position</th>
<th>A (m)</th>
<th>B (m)</th>
<th>R (kN)</th>
<th>F (kN)</th>
</tr>
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<tr>
<td>Upper Williamsona</td>
<td>centroid midspan</td>
<td>4.45</td>
<td>1.3</td>
<td>3.70</td>
<td>3.45</td>
</tr>
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<td>Chewaucan</td>
<td>centroid midspan</td>
<td>4.45</td>
<td>1.3</td>
<td>3.70</td>
<td>4.52</td>
</tr>
<tr>
<td>Elder Creek</td>
<td>centroid midspan</td>
<td>4.45</td>
<td>1.3</td>
<td>3.70</td>
<td>4.52</td>
</tr>
<tr>
<td>Dairy Creek</td>
<td>centroid midspan</td>
<td>4.45</td>
<td>1.3</td>
<td>3.70</td>
<td>4.52</td>
</tr>
<tr>
<td>Sycan Marsh</td>
<td>centroid midspan</td>
<td>4.45</td>
<td>1.3</td>
<td>3.70</td>
<td>4.52</td>
</tr>
<tr>
<td>Fishhole no.1</td>
<td>Rear axle midspan</td>
<td>4.45</td>
<td>1.3</td>
<td>3.70</td>
<td>4.52</td>
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<tr>
<td>Fishhole no.2</td>
<td>centroid midspan</td>
<td>4.45</td>
<td>1.3</td>
<td>3.54</td>
<td>4.43</td>
</tr>
</tbody>
</table>

a—two test trucks were used for this double lane bridge; A=4.17; B=1.40; R=3.75; F=3.33;

However, limited access to the underside of the glulam girders at four bridges only permitted taking deflection readings utilizing suspended rulers and an optical level. Testing at the three readily accessible bridges was more extensive and involved deflection and strain measurements under truck live loading. Midspan deflections were collected with Celesco string potentiometers attached to the bottomside of the beams. Strain measurements were collected with transducers manufactured by Bridge Diagnostics Inc. as shown in Figure 4. Strain transducers were mounted on each girder at the midspan, bottomside tension zone and at the cantilevered support, topside tension zone. The data...
collection was automatically collected by a Campbell-Scientific CR-10 datalogger unit.

**Figure 4:** Close-up view of string potentiometer and strain transducer attached to the tension laminations. The resistance micro-drilling tool is shown in the background.

**RESULTS**

4.4 LIVE LOAD TESTING

The live load deflection results of loading case 3 from the Elder Creek Bridge are shown in Figure 5.

**Figure 5:** Midspan deflections and cantilevered end uplift of the glulam girders at the Elder Creek Bridge.

**ACKNOWLEDGEMENT**

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**REFERENCES**


**5 CONCLUSIONS**

This poster presentation investigates older glulam girder bridges in the U.S. to determine the quality of the tension-zone laminations. Current load rating procedures require up to a 25 percent reduction in allowable bending stress for glulam girders manufactured prior to 1970. Diagnostic live load testing was utilized to determine if gains in rated bridge capacity can be achieved. Future work will focus on developing a rational and modified load rating procedure specific to these unique bridge structures.