Laboratory and Field Evaluation of a Composite Glued-Laminated Girder to Deck Connection

tech transfer summary

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RESEARCH PROJECT TITLE
Laboratory and Field Evaluation of a Composite Glued-Laminated Girder to Deck Connection

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The National Center for Wood Transportation Structures (NCWTS) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the NCWTS is to bring together academia, government, and industry to efficiently complete research, demonstration, and education that result in durable, cost-effective wood transportation structures to improve the transportation infrastructure of America and the world.

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Background and Problem Statement

Although developments in design details, preservatives, and advanced engineered concepts have significantly improved timber bridge performance over the past several decades, timber is sometimes considered to be a poor bridge building material. However, when properly designed and protected from the elements, timber is a structurally capable, cost-effective, and aesthetically pleasing material suitable for many applications.

Today, with tightened budgets and increasing degradation of existing bridge inventories, city, county, and state offices are seeking structurally adequate and cost-effective bridge alternatives. In response, Buchanan County, Iowa, has been working with the National Center for Wood Transportation Structures (NCWTS) and a timber fabricator to develop a structurally efficient, long-lived, next-generation timber bridge.

Objective

The objective of this project was to aid in the development of a next-generation timber bridge through the following:

- Laboratory and field testing of an innovative girder to deck connection detail designed to yield a composite structure
- Documenting construction of a next-generation timber bridge in Buchanan County
- Evaluating the bridge's field performance, including measuring changes in live load response over time and documenting the performance of a thin epoxy overlay wearing course on the bridge deck

Completed Buchanan County Bridge

Research Description

The timber bridge system developed for this research was a composite glue-laminated (glulam) girder-deck system using epoxy for the deck-girder connection and featuring a thin epoxy overlay wearing surface on the deck. This design was investigated through small- and large-scale laboratory testing of the connection detail and a field demonstration bridge using these design elements.

Small-scale laboratory tests were conducted on four different girder to deck connection types: lag bolts (the typical connection detail), epoxy only, epoxy with lag bolts, and epoxy with GRK screws, which are made of specially hardened steel to provide high tensile, torque, and shear strength. (The sharp threads and points bite into even hardwood, reducing the splitting effect due to smaller shanks).

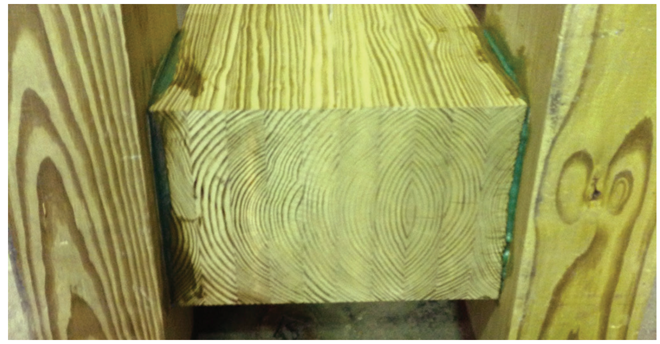
Push-out tests were conducted to evaluate the ultimate shear strength of each connection type. Large-scale laboratory tests were conducted on three two-girder systems spanning 41 ft:

- Transverse glulam deck panels lag-screwed to the girders
- Transverse glulam deck panels epoxied to the girders
- Precast concrete panels either epoxied to the girders or connected via shear studs and grout pockets

As a non-composite control, initial test data were collected from the first specimen with the glulam deck panels simply resting unattached on the girders. Because the concrete panel specimen did not remain elastic throughout the experiment, the data from this specimen were considered unreliable.

For the field testing, a demonstration bridge was designed and constructed in Buchanan County in 2015. The substructure of the bridge was composed of concrete abutments supported on steel H-pile sections, and the superstructure consisted of 11 southern yellow pine glulam timber girders. The deck consisted of 36 transverse glulam deck panels epoxied to the girders. An epoxy chip seal wearing course was applied to the bridge deck.

Three live load tests were completed on the structure, one post-construction in 2015, a second test one year later in 2016, and a third test one year after that in 2017. Midspan girder deflections along with strains in the girders and deck panels were collected during testing. The performance of the epoxy wearing surface was also observed.



End view of small-scale specimen showing epoxy connection

Glulam deck sections epoxied to large-scale laboratory specimen

Placing deck panel on the Buchanan County Bridge

Thin epoxy overlay being applied to deck of Buchanan County Bridge

Key Findings

- The small-scale laboratory tests indicated that the best overall joint connection was the epoxy and lag bolt connection (450 psi), followed by the epoxy-only connection (400 psi), the epoxy screw connection (375 psi), and the lag bolt–only connection (125 psi).
- The three joints with epoxy at least tripled the shear capacity of the lag bolt joint, while the addition of mechanical fasteners to the epoxy connection marginally increased performance.
- In the large-scale laboratory tests, a small increase in the load capacity and movement of the neutral axis was observed when the deck panels were affixed to the girders, as expected. Both indicate potential composite action.
- The epoxied connection exhibited approximately four times as much load transfer into the deck panels as the other specimens, indicating that this connection detail should improve composite action over the lag bolt-only connection.
- In the field tests, the measured deflections and bottom flange girder strains indicated that transverse load distribution for all load cases is adequate and as expected in design.
- Based on the recommend maximum deflection limit of L/360, the maximum recommended deflection for this demonstration bridge would be 2.4 in., which is more than 3.5 times the measured deflection under live load.
- Peak tensile strains measured in the girders were approximately 337 microstrain, corresponding to a stress of 640 psi, which is 23% of the design bending strength of the beams.
- The girder and deck strains indicated some level of composite action, although not likely substantial enough to be accounted for in design.
- The chip seal showed signs of cracking at the transverse deck panel joints. However, because the joints were previously filled with epoxy, the joints remained sealed and showed no signs of moisture intrusion on the underside of the deck.

Implementation Readiness and Benefits

Of the two key innovations featured in this research—the use of epoxy for the deck-girder connection and a thin epoxy overlay wearing surface on the deck—the girder-deck connection performed adequately. The limiting factor for attaining true composite action with either the epoxied or bolted glulam connection details is not purely the deck to girder connection. Rather, gaps between adjacent deck panels must be reduced and/or eliminated to achieve a noticeable and accountable increase in composite action.

This connection detail has the potential to increase viable bridge options for use not only for Iowa's roadways, but nationally and internationally as well.

The thin epoxy wearing surface on the deck performed better as an impermeable joint filler than a wearing surface. In the future, the combination of an initial epoxy overlay to fill the joints and seal the gaps followed by a well-designed asphalt wearing surface may help prolong the life of the structure.

Successful implementation, monitoring, and performance reporting of a well-performing timber bridge may help improve the negative perception of timber as a bridge building material.