

### EFFECTIVENESS OF GLUED LAMINATED COMPONENTS IN STRENGTHENING TIMBER BRIDGES

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#### Summary

A series of tests on three bridges in revenue service have demonstrated that the installation of glued laminated components can be effective in strengthening timber bridges. The tests were conducted by the Association of American Railroads (AAR) as part of its Timber Bridge Life Extension program in the fall of 1996 on a Union Pacific (former Southern Pacific line) in southwestern Texas. These tests represent the second in two phases of testing in which load-path information was used to determine the short-term effectiveness of using glued laminated stringers to strengthen existing timber bridges. Based on the initial results, the following conclusions can be made:

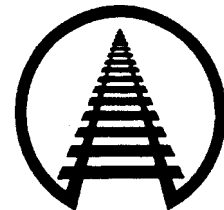
- Replacing the existing solid-sawn stringers (with typically more than 50 years of mainline service) with new glued laminated stringers caused an overall reduction in deflection.
- The use of glued laminated stringers caused the chord to behave more as a unit, with a more uniform load sharing among the stringers, as compared to solid-sawn stringers.
- The use of both new glued laminated stringers and the addition of a steel-plate ballasted deck promoted more uniform stringer deflections and reduced overall deflection.

Data was obtained from revenue-service trains and a test train operating at various speeds. The primary objective was to use static- and dynamic-load path measurements to quantify the effectiveness of using glued laminated components in two strengthening methodologies: replacing solid-sawn timber stringers with glued laminated stringers, and installing both new glued laminated stringers and a ballasted deck. Because the substructure components - piles, caps, bents - for all the test bridges were of adequate rating and rot-free, substructure strengthening was not required. Results from these strengthening techniques could vary on bridges with different traffic types, tonnage characteristics, bridge deck systems, design details, rail sizes and maintenance procedures. The long-term performance of these strengthening techniques has not been quantified.

Testing was done in conjunction with Iowa State University and the USDA Forest Service, Forest Products Laboratory.

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#### Suggested Distribution:

- Bridges and Roadway
- Maintenance of Way
- Maintenance Planning
- Track Maintenance

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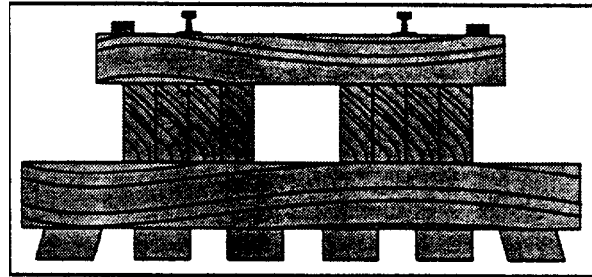
## INTRODUCTION AND CONCLUSIONS

In an effort to develop cost-effective techniques for strengthening and/or extending the life of existing timber bridges, the Association of American Railroads (AAR) tested three timber bridges in the fall of 1996. All three bridges were located in southwestern Texas, near Cline, D'Hanis and Pinto. The Cline and Pinto bridges were previously tested in the fall of 1995 (refer to TD 96-027) in order to establish the pre-strengthening load path and behavior characteristics. Based on this baseline information, 1996 post-strengthening testing was used to quantify the effectiveness of the two strengthening techniques: (1) installation of new glued laminated stringers (Pinto), and (2) the use of new glued laminated stringers with a new steel-plate ballasted deck system (Cline). The bridge at D'Hanis was selected for testing in 1996 because of its unique feature - the south chord is composed of four solid-sawn stringers while the north chord contains four glued laminated stringers. Because of this feature, testing on this bridge provided AAR researchers with a side-by-side (as opposed to a before-and-after) comparison of solid-sawn versus glued laminated stringer performance.

All three bridges are located along a main east-west route of the Union Pacific (UP) (former SP) which carries heavy-axle-load traffic. As expected, results from the tests indicate that the glued laminated stringers (with and without the ballasted-deck) experienced reduced deflections and responded more uniformly to loading conditions. Furthermore, the tests illustrate that there is still little continuity of stringer deflection over the bents as was noted in the 1995 test results.

## BRIDGE DESCRIPTIONS

The configurations of the open-deck bridge (D'Hanis), Pinto and the Cline bridge prior to strengthening) are very similar (refer to Exhibit 1). Exhibit 2 shows the configuration of the converted ballasted-deck Cline bridge which differs only with regards to the superstructure. Note that the ballasted-deck configuration utilizes a steel plate to contain the ballast and distribute load to the stringers. In order to accommodate the additional dead load due to the ballast and steel deck, a fifth stringer is installed approximately 20 inches from the four-ply chord. All three bridges have substructures (bents) composed of nominal 14-inch square caps supported by six piles at the intermediate supports and five piles at the abutments. The Cline and Pinto bridges have single caps whereas the bridge near D'Hanis has double caps. Nominal bent spacing is 15 feet center-to-center.



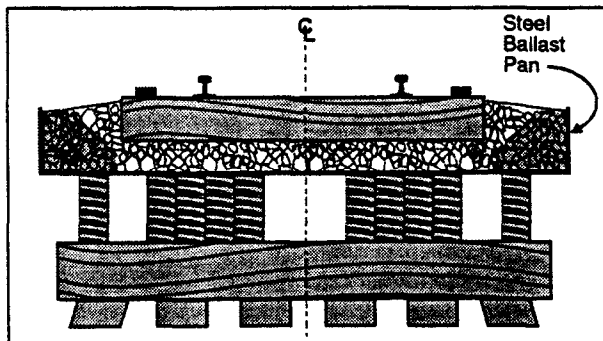
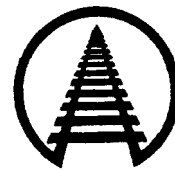
**Exhibit 1: Cross-Section View of an Open-Deck Timber Bridge**

The superstructure for each bridge consists of two longitudinal packed chords, each containing four stringers. The solid-sawn stringers on the D'Hanis bridge are 7.75 inches wide by 16.25 inches deep. The glued laminated stringers have a larger moment of inertia, measuring 6.75 inch wide by 18 inches deep. The glued laminated stringers were chosen for several reasons, including availability, mechanical properties and cost. Actual stringer sizing was based both on availability and strength rating. The majority of the stringers were 30 feet in length and continuous over two spans. Individual stringers were bolted together with 0.75-inch-diameter bolts at the bearings and at midspan for lateral stability only (not intended to promote load sharing between stringers). All three bridges were originally constructed around 1937 using creosote-treated Douglas fir-larch.

There were also several notable differences between the bridges. The Cline bridge has 119 lb/yd continuous welded rail, whereas the D'Hanis and Pinto bridges have 136 lb/yd continuous welded rail. The solid-sawn stringers in the D'Hanis bridge were installed in 1989 while the solid-sawn stringers for the Pinto and Cline bridges were installed in 1937. The glued laminated stringers in the D'Hanis bridge were installed in 1990 whereas the glued laminated stringers in the Pinto and Cline bridges were installed in 1996. That same year, the Cline bridge also received a ballasted deck, making it easier to maintain track surface, since a turnout is located just off the west end of the bridge.

## TEST PROCEDURES

All three bridges were instrumented to obtain deflections and vertical rail forces. For the Cline and Pinto bridges, testing was conducted on two adjacent spans (one end span and one intermediate span). For the bridge at D'Hanis, an intermediate span near the eastern and western ends of the bridge was tested. Vertical deflections were measured using displacement transducers



**Exhibit 2: Cross-Section View of a Ballasted-Deck Timber Bridge**

referenced to ground, on several stringers at midspans and adjacent to the bents.

Testing was conducted with both revenue-service trains and a test train provided by the railroad. A test train, consisting of one six-axle EMD locomotive and three loaded hopper cars, was used to evaluate the dynamic response at all three bridges. Load tests with the test train were completed at crawl speed (approximately 2 mph) and at speeds of approximately 15, 30, and 40 mph. Readings from revenue-service trains at speeds ranging from 25 to 62 mph were also recorded and analyzed.

## RESULTS AND ANALYSIS

### Chord Deflections: Glued Laminated vs. Solid-Sawn Stringers

Deflection measurements provide indications of stringer bending as well as movement at the ends where stringers bear on the bents. Exhibit 3 shows a comparison of relative stringer midspan deflections for the south and north chords of the D'Hanis bridge (span 8). Note that relative midspan deflection is defined as the absolute midspan deflection (relative to the ground) minus deflections occurring at the adjacent bents. As the exhibit indicates, the magnitude of the relative deflections for the north chord (glued laminated stringers) are much smaller than the corresponding deflections for the solid-sawn stringers of similar age in the south chord. Moreover, the deflections of the glued laminated stringers are more uniform.

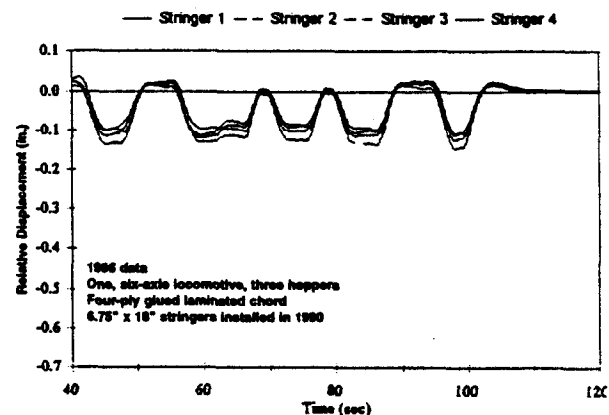
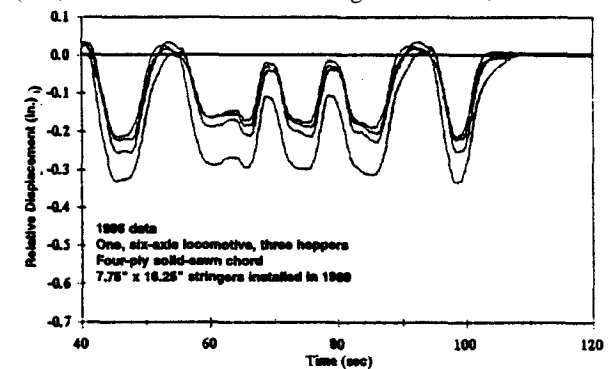
It is important to note three key points:

- The unique nature of this bridge provides researchers with a side-by-side comparison based on the same traffic.
- In contrast to the solid-sawn stringers at the Cline and Pinto bridges, the solid-sawn stringers installed

in the D'Hanis bridge are relatively new with minor visible horizontal shear cracks at some locations.

- The solid-sawn stringers have a similar time in service as the glued laminated stringers.

For the bridge at Pinto, midspan deflection data from the solid sawn and glued laminated stringers illustrated the same tendencies: glued laminated stringers exhibited smaller deflections and behaved more uniformly under loading. The solid-sawn stringers from the Pinto were approximately sixty years old when tested in 1995 and deflected more than the newer solid-sawn stringers from the D'Hanis bridge. Nonetheless, the deflection magnitude and load sharing performance of the glued laminated stringers agreed with the results from the D'Hanis bridge. The more uniform load-sharing performance of the glued laminated stringers is expected in that they are more of a uniform/engineered product than the solid-sawn stringers. This concept also applies to deflection magnitudes due to their superior engineering qualities as well as their larger moment of inertia ( $I=2,771$  in<sup>4</sup> for solid-sawn stringers and  $I=3,280$  in<sup>4</sup> for



**Exhibit 3: Comparison of Relative Midspan Deflections at D'Hanis**



the glued laminated stringers). Based on the 18 percent increase in moment of inertia, one would expect a 16 percent reduction in deflection.

#### Chord Deflections: Glued Laminated with Ballasted-Deck vs. Open-Deck Solid-Sawn Stringers

Exhibit 4 shows a comparison of relative stringer midspan deflections for the north chord of the Cline bridge (span 4). As with the solid-sawn versus glued laminated stringer performance results cited above, there was a dramatic improvement in terms of deflections and load distribution at this bridge. In fact, when comparing the 1996 test results from exhibits 3 and 4, it is evident that the addition of the ballasted deck further reduced the deflections of the glued laminated stringers and also further reduced the amount of deflection scatter.

This reduction in deflection and scatter deflection may be attributed to three items: the ballast, the steel plates which are used to contain the ballast, and the extra stringer which supports the ballasted deck. It is likely that composite action of the ballast/steel plates contribute to the load distribution (and hence induce uniform loading of the stringers) although stresses were not measured on the steel plate to quantify this. In addition, it is worth noting that the dead weight of the ballast on the stringers promoted better dynamic bearing conditions by taking up gaps from the initial construction.

#### Chord Deflections: Comparison of New vs. Older Stringers

Despite having an age difference of five or six years, it was observed that the relative deflections of the glued laminated stringers from the D'Hanis bridge are similar in magnitude to the relative deflections for the new glued laminated stringers in the Pinto bridge. This trend is valid for both midspan and end-span relative deflections under revenue-service and test-train loads. Further observations regarding the long-term, in-service performance of the glued laminated stringers in the D'Hanis bridge is not yet available. The glued laminated stringers in the D'Hanis bridge were some of first to be installed on this line.

Based on 1995 test results, the relative deflections for the solid-sawn stringers (installed in 1937) at Pinto and Cline were considerably larger than the relative deflec-

tions for the newer solid-sawn stringers at D'Hanis. For instance, the maximum observed relative deflection at Pinto in 1995 was approximately 0.5 inch, whereas the maximum relative deflection at D'Hanis was approximately 0.3 inch

#### ACKNOWLEDGMENTS

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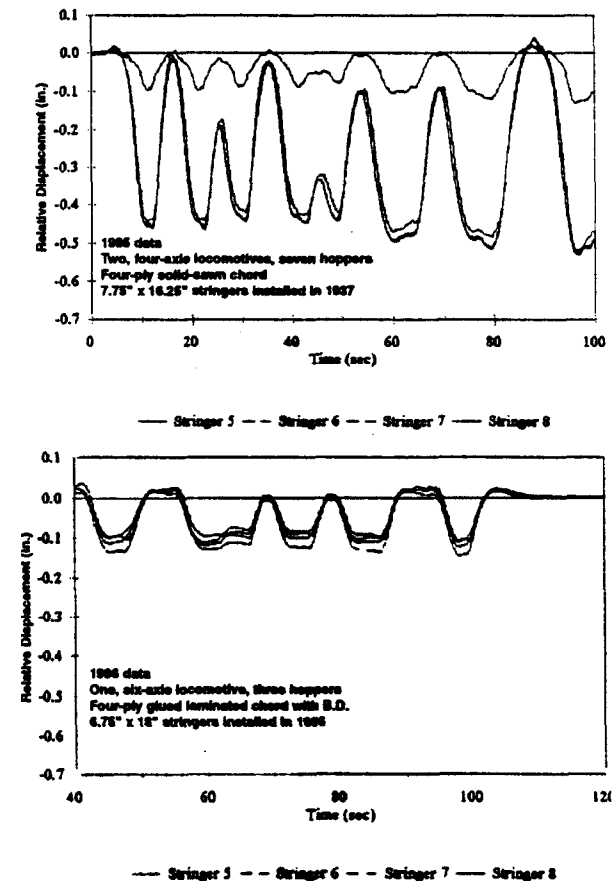


Exhibit 4. Comparison of 1995 and 1996 Relative Midspan Deflections at Cline

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