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Benchmark Testing of Timber Open Deck Bridge Ties

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This Technology Digest (TD) supports TD 11-035 which describes new guidelines developed for alternative material open deck bridge ties. It is important that alternative material ties perform at least as well as timber. Results of testing described in this TD were used to establish minimum deflection requirements and to verify that maximum deflection recommendations are sensible when compared to timber tie performance.

Summary

In 2009, The Transportation Technology Center, Inc. (TTCI) began investigating alternatives to timber ties for open deck bridges as part of the Association of American Railroads' Strategic Research Initiatives. In 2010, TTCI carried out a number of benchmarking tests on timber ties. The objective of the tests was to help establish and verify the load and deflection guidelines for alternative material open deck bridge ties. The guidelines recommend that alternative material ties demonstrate the ability to carry a design live load of 53,000 pounds per wheel, have a maximum deflection of 0.33 inch to 0.43 inch under design live load before factor of safety, depending on intended girder spacing, and have a minimum deflection of 0.10 inch to 0.12 inch, depending on intended girder spacing.

Initial tests were conducted on four types of open deck bridge ties installed on the vintage open deck steel span at the Facility for Accelerated Service Testing (FAST). Installed ties include 12-foot-long solid sawn southern yellow pine (SYP), 12-foot-long glued laminated (glulam) Douglas fir, and 12-foot-long solid sawn white oak as well as 18-foot-long Douglas fir ties used to support side walkways. Mid tie and rail seat deflections of each tie type were measured under traffic at FAST. The Douglas fir glulam ties had very similar performance with a median mid tie deflection of about 0.14 inch. The remaining median deflections varied between 0.14 inch and 0.23 inch. The 5th percentile value of these measurements was used to establish a minimum recommended deflection of 0.11 inch under a live load test.

A second series of tests was conducted in the laboratory. Deflections of Douglas fir glulam ties, white oak, and SYP solid sawn ties were measured under a 27,000-pound test load as recommended in the new design guidelines. Measured deflections were well within the new minimum and maximum deflection recommendations.

In addition, two SYP ties were tested to failure. The first tie tested performed satisfactorily and supported 60,000 pounds, which is 130 percent of the recommended 53,000-pound test load, before exhibiting loud cracking noises. However, the second tie failed at 52,300 pounds, which is slightly less than the recommended test load.

Results indicate that because not all timber ties can withstand the 53,000-pound design load, the new strength recommendations may be conservative compared to demonstrated timber tie performance. However, a conservative design for strength is appropriate for alternative material ties, because material consistency and long-term performance of alternative materials will likely not be as well established as for timber.

The deflection limitations provide a considerable amount of latitude compared to the strength recommendation. This is appropriate because the deflection limitation is primarily a serviceability concern, whereas the strength recommendation is a safety concern.



INTRODUCTION

In 2009, TTCI began investigating alternatives for timber ties on open deck bridges as part of the Association of American Railroads’ Strategic Research Initiatives. As part of this effort, TTCI has recommended design guidelines for alternative material for open deck bridge ties.

In 2010, TTCI carried out a number of benchmarking tests to help determine requirements for alternative material ties for open deck bridges. These tests were carried out both in the Rail Dynamics Laboratory and on the vintage steel span installed at the Federal Railroad Administration’s FAST at the Transportation Technology Center. Results of the benchmarking tests were used in the development of tie load and deflection recommendations.

Testing on the Vintage Span at FAST

Benchmark testing of timber open deck bridge ties was carried out under 315,000-pound freight traffic at FAST on four types of open deck bridge ties installed on the Vintage open deck steel span. The span is a 55.4-foot riveted steel deck plate girder, with 8-foot girder spacing. Installed ties include 12-foot-long solid sawn SYP, 12-foot-long Douglas fir glulam, and 12-foot-long solid sawn white oak. In addition, 18-foot-long solid sawn Douglas fir ties are installed to support the walkway. Figure 1 shows the installation layout on the vintage span. Table 1 shows the tie dimensions. Ties are spaced at 14 inches, center to center, except at the ends of the span where they are tightly spaced.

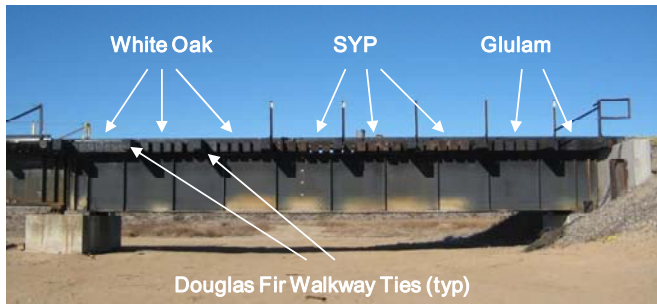


Figure 1. Tie Locations on Vintage Span at FAST

Table 1. Open Deck Bridge Tie Dimensions

Tie Type	Height (inches)	Width (inches)	Length (feet)
Southern Yellow Pine	11.5	9.9 to 10	12
Douglas Fir	12	10	18
White Oak	12	10	12
Douglas Fir Glulam	12	12	12

Deflections were measured at mid tie and at each rail seat for two ties of each type under FAST traffic. Figure 2 shows the distribution of measured mid tie deflections, and Figure 3 shows the median values. One of the Douglas fir walkway ties (Douglas Fir 1) deflected much less than the others due to its installation between two slightly taller Douglas fir glulam ties. The remaining Douglas fir walkway ties and the Douglas

fir glulam ties had very similar performance with a median deflection of about 0.14 inch. The remaining median deflections varied from 0.14 inch for White Oak 1 to 0.23 inch for SYP 2.

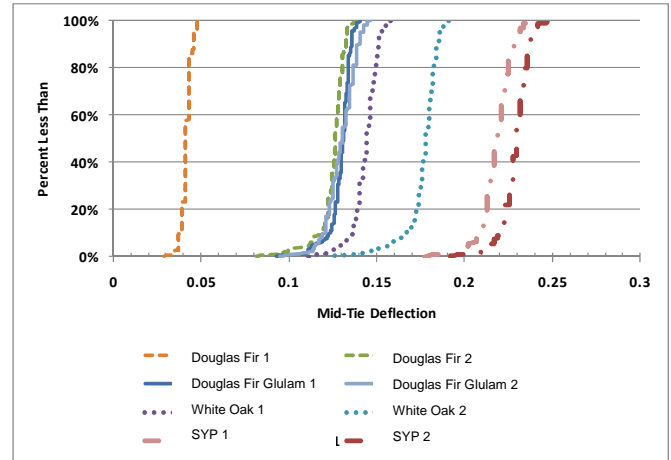


Figure 2. Cumulative Frequency Graph – Deflection of all Timber Bridge Ties under Train at FAST

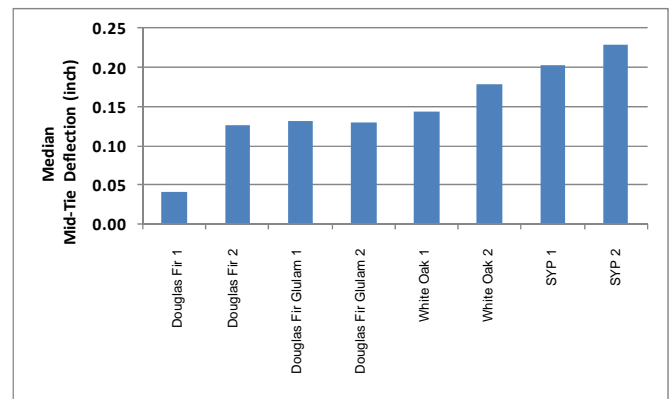


Figure 3. Median Deflection of all Timber Bridge Ties under Train at FAST

Deflection Guidelines

A maximum deflection for alternative material ties is recommended to ensure that the ties can carry the required load and maintain proper gage. A minimum deflection is recommended in an attempt to provide some of the beneficial properties of timber ties such as distribution of axle loads to adjacent ties and attenuation of impacts.

Maximum recommended deflections are based on Chapter 7 of the AREMA *Manual for Railway Engineering*¹ guidelines of span length divided by 250. For purposes of open deck bridge ties, the span is taken as the center-to-center spacing of the girders.

The minimum tie deflection value for 8-foot girder spacing was based on the 5th percentile value of the measured deflections. Once the data from the Douglas Fir 1 was omitted due to the dimensional difference with adjacent ties, the 5th percentile of the stiffest timber ties was about 0.11 inch. This value was chosen as a minimum recommended deflection for alternative material ties. Recommended deflections for ties

for 7- and 9-foot girder spacings were scaled accordingly. The deflection limitations provide a considerable amount of latitude compared to the strength recommendation. This is appropriate, because the deflection limitation is primarily a serviceability concern, whereas the strength recommendation is a safety concern.

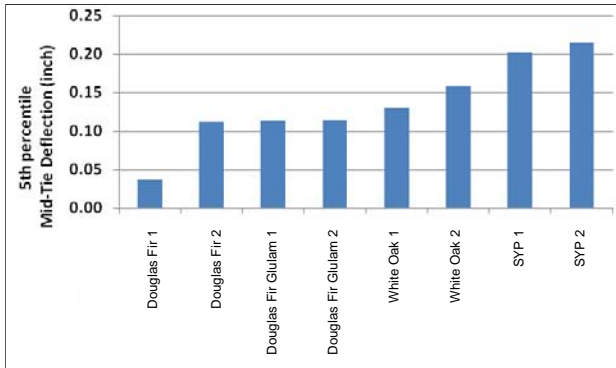


Figure 4. 5th Percentile Deflection of all Timber Bridge Ties under Train at FAST

The 5th percentile of measured wheel loads on the bridge at FAST are approximately 40,000-45,000 pounds.² Using the AREMA Chapter 15 design recommendation that wheel loads are distributed over three ties, the 5th percentile load at FAST would be about 14,000 pounds per wheel. This is about ½ the recommended 27,000 pound test load. Based on this, the 0.11-inch minimum deflection is somewhat less restrictive than the test results would indicate.

Table 2 summarizes the recommended deflection requirements.

Table 2. Alternative Bridge Tie Test Deflection Requirements at 27,000 pounds per Rail Seat

Girder Spacing (foot)	Applied Load per Rail Seat (pounds)	Minimum Deflection (inch)	Maximum Deflection (inch) (AREMA 7)
7	27,000	0.10	0.33
8	27,000	0.11	0.38
9	27,000	0.12	0.43

Laboratory Testing

Laboratory tests were performed on three of the tie types installed on the vintage bridge at FAST: solid sawn SYP, solid sawn white oak, and Douglas fir glulam. Two ties of each type were tested for deflection under the 27,000-pound test load, and two SYP ties were tested to failure. A test rig was developed for the tests based on a design by Madsen and Sweeney.³ Figure 5 shows a schematic of the test rig. Both mid tie and rail seat deflections were measured. Because all three tie types were designed for 8-foot girder spacing, the test rig was configured accordingly.

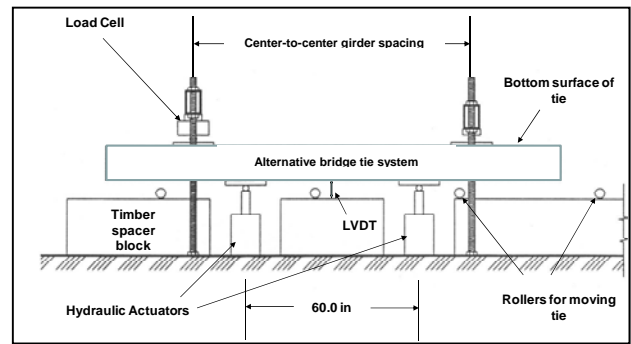


Figure 5. Tie Bending Test Apparatus

Figures 6 through 8 present the results for mid tie deflection. All of the ties tested were within the recommended minimum and maximum deflections for mid tie deflection at the recommended test loads.

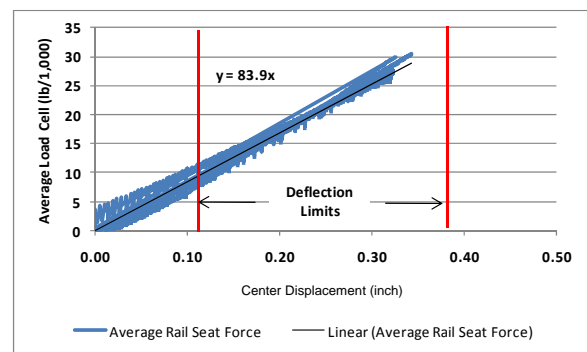


Figure 6. Force/Displacement Diagram – SYP – Mid Span

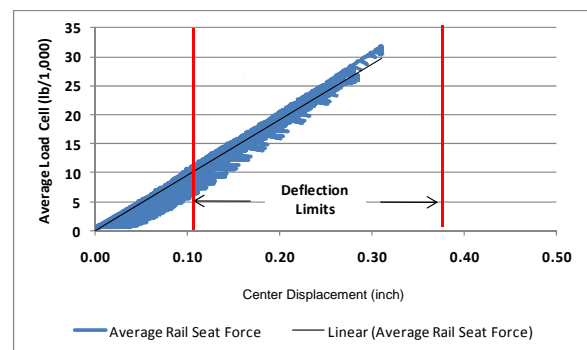


Figure 7. Force/Displacement Diagram – White Oak – Mid Span

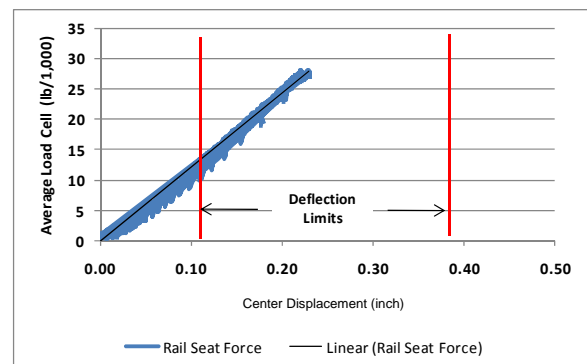


Figure 8. Force/Displacement Diagram – Douglas Fir Glulam – Mid Span

Two of the SYP ties were tested to failure. Figures 9 and 10 show the applicable force-deflection diagrams. Failure, indicated by a loud cracking noise, occurred at about 60,000 pounds of applied load per rail seat for SYP1. For SYP2, failure occurred at about 52,300 pounds per rail seat. In this case, failure was indicated by visible distress as shown in Figure 11. Note that both ties met the minimum and maximum deflections at 27,000 pounds, which is the recommended applied load for the deflection test. At the design load, SYP1 did not show signs of excessive deflection or failure. However, SYP2 failed at approximately the design load. The failure mode appeared to be bending rupture of the tension fibers.

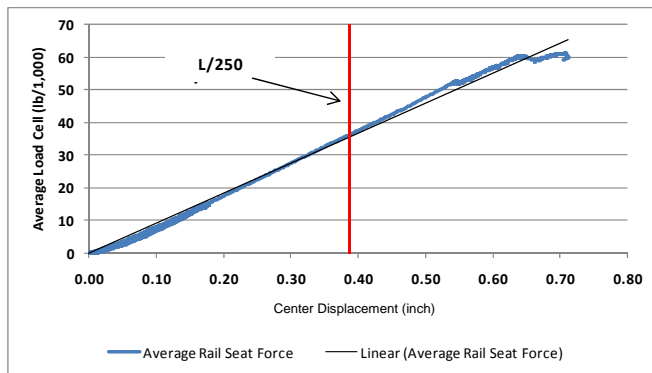


Figure 9. SYP 1 – Test to Failure, Cracking Noise Noted

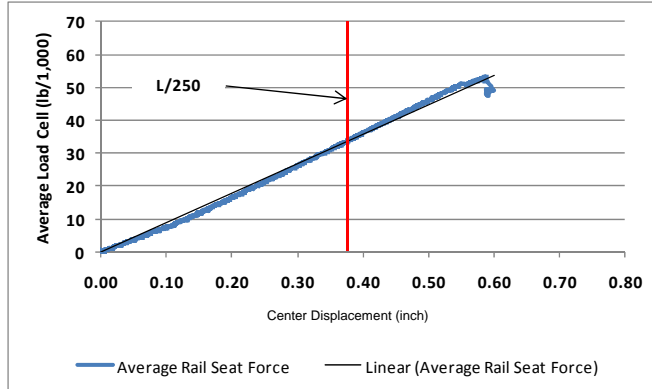


Figure 10. SYP 2 – Test to Failure



Figure 11. SYP 2 – Failure at Bottom Surface of Tie

DISCUSSION

Results of testing to failure indicate that not all timber ties can withstand the design load of 53,000 pounds. However, timber is a material with a long history of use in structures, and its failure mechanisms are well understood. While results may indicate that the 53,000-pound design load is conservative, it is considered appropriate for alternative material open deck ties, because it is likely to be applied to new materials for which material characteristics are only now being established.

ACKNOWLEDGEMENTS

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