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Evaluation of Alternative Open Deck Bridge Ties at FAST

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Summary

In an effort to investigate alternatives to solid sawn timber ties for open deck bridges, Transportation Technology Center, Inc., Pueblo, Colorado, is testing two alternative tie types — glued-laminated Douglas fir ties and fiber-reinforced foamed urethane (FFU) bridge ties — on the steel bridge at the Facility for Accelerated Service Testing (FAST). FFU is similar to fiberglass.

Both types of ties underwent laboratory testing before being installed on the open deck steel bridge at FAST. Performance of the ties is being monitored by visual observations and deflection measurements.

Observations to date:

- Glued-laminated Douglas fir ties have accumulated over 310 million gross tons (MGT) of heavy axle load (HAL) traffic at FAST with no maintenance required.
- FFU ties have accumulated over 130 MGT of HAL traffic at FAST with no maintenance required.
- Both types of ties meet the preliminary structural performance guidelines for alternative engineered ties for open deck bridges.
- Solid sawn timber ties of three species (white oak, Douglas fir, southern yellow pine) on this span, serving as control ties, have accumulated over 310 MGT of HAL traffic at FAST with no maintenance required.

Railroad bridge engineers have noted increasing expenses and decreasing life of traditional solid sawn timber bridge decks. This has prompted interest in alternatives that might provide lower life-cycle costs. Additional tonnage exposure is needed in order to quantify long-term performance of these tie types.

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INTRODUCTION

Railroads have noted reduced bridge deck life in revenue service. This has prompted Transportation Technology Center, Inc. (TTCI) to investigate alternatives to solid sawn timber ties for open deck bridges as part of the Association of American Railroads' Strategic Research Initiatives.

TTCI has various solid sawn timber bridge ties including species such as red oak, white oak, Douglas fir, and southern yellow pine installed on the steel bridge at FAST.

For the installation of the vintage steel span in late 2009, Union Pacific Railroad (UP) donated Douglas fir glued-laminated (glulam) timber ties for testing. The UP has used glulam timber since the mid-1990s to replace stringers but not ties in timber bridges, a practice begun by predecessor Southern Pacific.[1,2] One UP bridge near Krotz Springs, Louisiana, has had glulam timber ties installed for more than 10 years. Until recently, this was a unique installation for ties on UP.

Sekisui produces an FFU sleeper (crosstie) for open deck bridges and in 2011 donated ties for testing on the FAST steel bridge. Ties of this type have been used on railroad bridges in Japan for a number of years.

TTCI testing consisted of initial laboratory load applications, followed by installation on the vintage riveted steel deck-plate-girder test span at FAST. This span is much like many of the open deck steel spans still in revenue service in North America today. It has 8-foot girder spacing making it an excellent test bed for structural bridge ties. The test span is subjected to 100-150 MGT per year of HAL traffic.

TESTING AT FAST

Figure 1 shows the tie layout for the FFU ties. Note that there is one 18-foot long Douglas fir walkway support tie separating two adjacent 5-tie panels.

The Douglas fir glulam ties are installed in two similar panels at the east end of the span.

TTCI fastened the ties to the steel girder using hook bolts every fourth tie. Rail and tie plates were fastened using cut spikes. All ties were fastened to an outside spacer timber with lag screws. Note that this installation is typical of North American bridge installation practice; in this case closely following plans used by Norfolk Southern, the donor of the vintage span.

At FAST, the ties are subjected to 315,000-pound HAL traffic at 40 mph. The FAST train operates in both directions over these ties. The Douglas fir glulam ties have accumulated more than 310 MGT of HAL traffic at FAST. The FFU ties have accumulated more than 130 MGT.

Measurements of tie deflections were taken at mid-tie and at each rail seat. Figure 2 shows the reference frame under the span at FAST.

Figure 1. Bridge Deck Tie Tests on Vintage Span

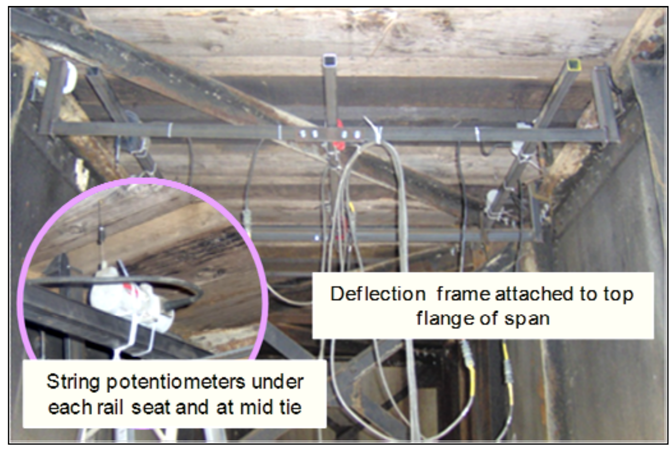

Figure 2. Reference Frame for Measuring Tie Deflection at FAST

Figure 3 shows the average deflection values at center of tie and beneath the rail seats for two different ties of five various types: southern yellow pine, Douglas fir (solid sawn), white oak, Douglas fir glulam, and FFU. These deflections are all within the recommended range of values for alternative bridge ties.[3] The Douglas fir glulam ties are slightly stiffer than the white oak ties. The FFU ties are slightly less stiff than the southern yellow pine ties. The Douglas fir glulam ties have essentially the same deflections as the Douglas fir solid sawn ties. As expected, the tie center deflections are greater than those under the rail seats for all tie types. The deflection values measured at FAST for the various tie types reflect the same relative deflection trends as measured in laboratory tests.[4] This trend provides additional support for the recently recommended laboratory guidelines.[2]

Figures 4 and 5 show tie deflections measured at FAST for two different FFU ties beneath both rail seats (inside and outside) as well as at center of tie. Also shown are the deflections in the same locations measured during laboratory testing.

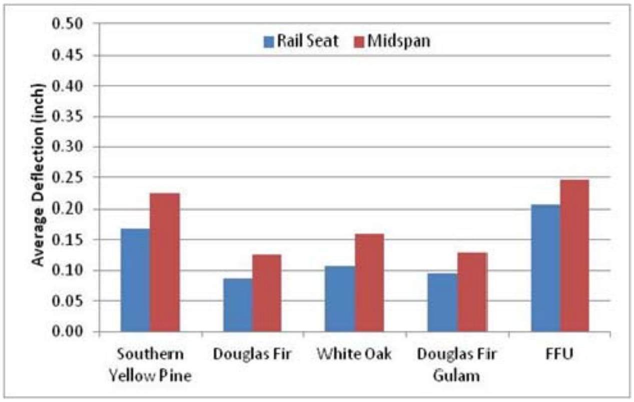

Figure 3. Average Deflection of Various Solid Sawn Timber and Alternative Ties under FAST Train

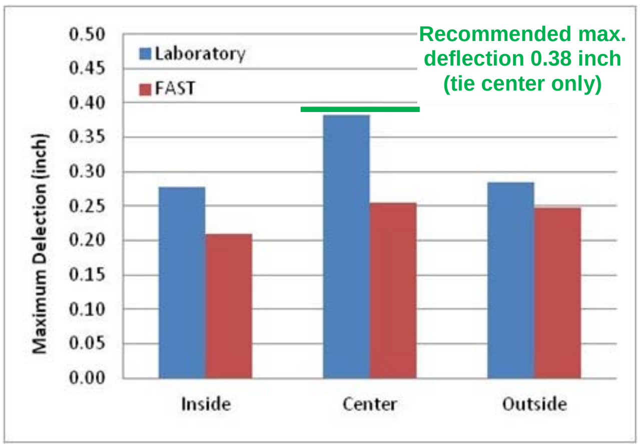

Figure 4. FFU Tie 1
Laboratory vs. FAST Deflection Comparisons

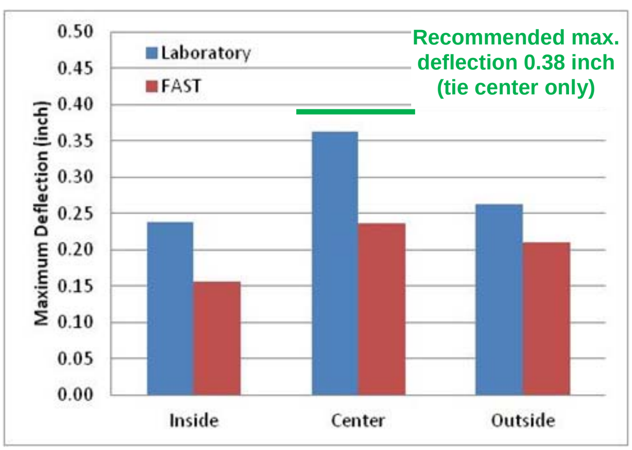

Figure 5. FFU Tie 2
Laboratory vs. FAST Deflection Comparisons

For the laboratory testing, a 27,000-pound load was applied at each rail seat. This load is based on a Cooper E-80 wheel load of 40,000 pounds with 100-percent impact, distributed evenly over three ties, per AREMA Chapter 15.[5] At FAST, the nominal wheel loads are 39,375 pounds, nearly the same as the design load. Past experience at FAST suggests that the impact is not as high as 100 percent, because the FAST train usually does not have any flat wheels, and the rail over the bridge at the time of measurement was continuously welded with no rail joints. Actual distribution of wheel loads to ties has not been measured on the FAST steel bridge. Considering the known reduced impact at FAST, the laboratory test load and design distribution seem reasonable in light of these test results. These tests are similar to those conducted previously on various timber ties.[4] The FFU tie deflections are most similar to those measured for southern yellow pine ties.

LABORATORY TESTING

A test rig, based on one designed by Sweeney and Madsen,[6] was set up in the laboratory (Figure 6). The test rig simulates the girder spacing of the span and load points of the rail. Spacing of the reaction points was set up to replicate center-to-center girder spacing (8 feet). Spacing of the load points was 60.0 inches for standard gage track.

Figure 6. TTCI Laboratory Test Rig

For both the Douglas fir glulam ties and the FFU ties, two randomly chosen ties were tested in the laboratory. These ties were checked for defects before testing. A deflection test and a design load test were performed in the laboratory. Each test was performed twice, once with the load applied in approximately 2 to 5 minutes and once with the load applied more slowly, over 20 minutes.

The deflection test measured minimum and maximum tie center deflection under loads of 27,000 pounds (live load before factor of safety) at each rail seat. Values were compared to previously defined minimum and maximum deflection values.[3]

In addition, a design load test was performed. For this test a load of 53,000 pounds per rail (live load including factor of safety) was applied. A visual inspection was made to the tie after this test to check for any damage.

After these tests, the bottoms of the FFU ties were milled so they would fit over the protruding rivet heads on the top surface of the vintage girder on the bridge at FAST, where they were installed for in-service testing. Figure 7 shows the milling for one girder flange on the bottom side of an FFU tie. There are two lines of rivets on each of the top flanges. The milling pattern allows for the ties to move longitudinally along the top flange. During installation at FAST, the milling facilitated quick and accurate lateral location of the ties on the girders. The milling of the FFU ties to clear the rivets was done based on the vendor's recommendation. None of the timber ties installed on the span were milled. The timber ties were set directly on top of the rivets and allowed to seat under train traffic.

Figure 7. FFU Tie Milled to Clear Rivet Heads on Top Flange

After milling, the ties were tested again in the laboratory before being installed at FAST. Figure 8 shows the deflection differences for one FFU tie before and after milling. Testing of a second FFU tie yielded similar results. Under the live load of 27,000 pounds, both ties stayed below the recommended maximum deflection of 0.38 inch for tie center deflection for an 8-foot girder spacing. Both FFU ties provided tie center deflections greater than the 0.11-inch recommended minimum for an 8-foot girder spacing. Both ties also performed well under the 53,000-pound load. No damage was observed.

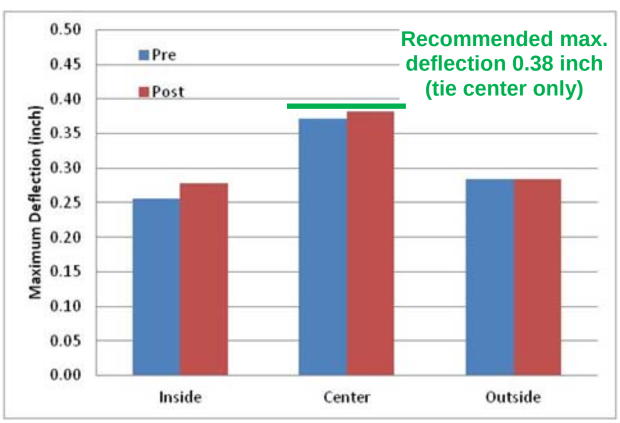

Figure 8. FFU Tie 1 Deflections under 27,000 Pounds, 2-5 Minute Loading, Before (Pre) and After (Post) Milling

Figure 9 shows the difference in deflection when the ties were loaded slowly (20 minutes) and when the ties were loaded more quickly (2-5 minutes). There is no significant difference in the performance of the ties at the two loading rates.

Laboratory test results for the Douglas fir glulam ties were reported previously.[4] Deflections for these ties under laboratory test loads were closer to the minimum recommended value for an 8-foot girder spacing.

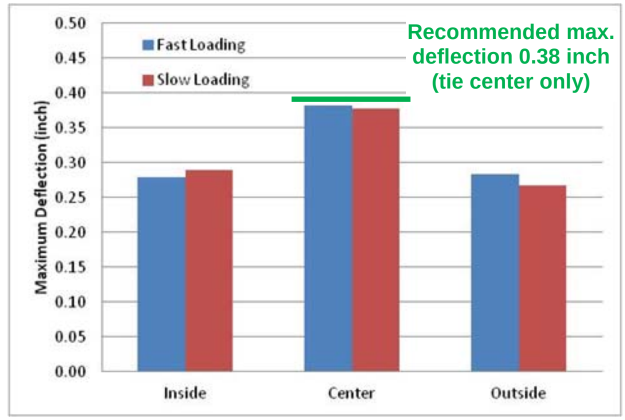

Figure 9. FFU Tie 1 Deflections under 27,000 Pounds, Post Milling, at Two Loading Rates

FUTURE TESTING

The performance of the test ties will be monitored for a period to be determined at FAST. Ideally bridge deck ties should last for thousands of MGT of traffic. Subject to tie condition and other test requirements, TTCI anticipates that the test will continue for several years. The ties will be visually inspected for condition and observed under traffic on a regular basis. The failure criteria noted under the lab tests will apply.

In addition, fastener condition and the ability to hold track geometry will be assessed. Once a service history has been established, the inspection period may be extended. Deflection tests will be repeated after additional tonnage accumulation.

ACKNOWLEDGEMENTS

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