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Evaluation of Alternative Bridge Ties at FAST and Revenue Service

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Summary

Results to date of Transportation Technology Center, Inc.'s (TTCI) long-term evaluation of two alternative bridge ties have been encouraging. In 2009, TTCI began investigating alternatives to timber ties for open deck bridges as part of the Association of American Railroads' (AAR) Strategic Research Initiative (SRI) program. TTCI is now evaluating the long-term performance of alternative bridge ties that meet recommendations based on laboratory testing. Two alternative bridge tie types are currently being evaluated as part of this study; namely, Douglas fir glued laminated timber (glulam ties), and fiber-reinforced foamed urethane (FFU) ties. In-track testing under heavy-axle loads (HAL) is currently underway for both types of ties at the Facility for Accelerated Service Testing (FAST) and for an additional set of FFU ties at the eastern mega site near Princeton, West Virginia.

The following summarizes the most recent observations to date:

- None of the warp or twist observed for the solid-sawn timber ties, which are being used as the control for the testing at FAST, has been observed for the glulam and the FFU ties.
- No cracking has been noted in the FFU ties and only minor cracking has been noted in the glulam ties. By comparison, some of the solid-sawn ties have significant cracks that have opened up to allow water into the heart of the tie.
- The Douglas fir glulam ties have accumulated more than 900 million gross tons (MGT) of HAL traffic to date at FAST with no maintenance required.
- The FFU ties have accumulated more than 700 MGT of HAL traffic at FAST with no maintenance required.
- Solid-sawn timber ties of three species (i.e., white oak, Douglas fir, and southern yellow pine), serving as the control ties in this experiment at FAST, have accumulated more than 900 MGT of HAL with no maintenance required.
- After four years in revenue service at the eastern mega site, the FFU ties have shown similar performance to their counterpart ties at FAST with no issues observed and only minute decreases in gage-widening resistance from year to year.

Additional tonnage exposure is needed in order to provide a sufficient evaluation of the long-term performance of these ties under heavy-haul operations.

This investigation is being undertaken by the TTCI under the joint sponsorship of the AAR, through its SRI program, and the Federal Railroad Administration.



INTRODUCTION

In recent years, railroads have noted reduced bridge deck life and increased timber tie expense in revenue service. In addition, railroads have noted a limited supply of solid sawn timbers in large bridge tie sizes and a decline in quality of large solid sawn timbers due to fewer old growth trees (in the sizes required for bridge timbers) being harvested. This has prompted Transportation Technology Center, Inc. (TTCI) to investigate alternatives to solid-sawn timber ties for open deck bridges as part of the AAR’s Strategic Research Initiatives Program.

TTCI has various solid-sawn timber bridge ties, including species such as red oak, white oak, Douglas fir, and southern yellow pine, installed on two steel bridges at the Facility for Accelerated Service Testing (FAST) in Pueblo, Colorado.

For the installation of the 55.5-foot riveted steel girder span in late 2009, Union Pacific Railroad (UP) donated Douglas fir glued laminated timber, or glulam, ties for testing. The UP has used glulam timbers since the mid-1990s to replace stringers — a practice initiated by predecessor Southern Pacific.¹ Still, only recently has glulam been used for deck ties on a bridge. One UP bridge near Krotz Springs, Louisiana, has had glulam ties installed for almost 20 years — until recently, this was a unique installation for UP.

Sekisui Chemical Co., Ltd. of Japan produces a fiber-reinforced foamed urethane (FFU) crosstie for open deck bridges. In 2011, the company donated ties for testing on the steel bridges at FAST and in revenue service at the eastern mega site. Ties of this type have been used on railroad bridges in Japan for several years.

Neither the glulam ties nor the composite bridge ties will have the length and section size price sensitivity of solid sawn timbers (e.g., making a bigger tie adds only the cost of the extra material; whereas, making a larger solid sawn Douglas fir tie adds years for more time to grow).

Prior to field installation, both Norfolk Southern Railway (NS) and TTCI conducted laboratory load applications to evaluate structural properties, spike pullout resistance, and gage-widening resistance. The lab testing was followed by installation on the 55.5-foot riveted steel deck plate girder test span at FAST.^{2,3} This span is built similar to many of the open deck steel spans still in North American revenue service today. It has an 8-foot girder spacing, making it an excellent test bed for structural bridge ties. The installation of the FFU ties at the eastern mega site was completed on a 67-foot riveted steel deck plate girder span with 6.5-foot girder spacing.

TESTING AT FAST

Figure 1 shows the tie layout for the FFU ties at FAST. Note that there is one 18-foot-long Douglas fir walkway support tie separating two 5-tie panels. The Douglas fir glulam ties are installed similarly in two 5-tie panels at the east end of this span.

TTCI fastened the ties to the steel girder using hook bolts every fourth tie. Rail and 14-inch tie plates were attached using cut

spikes. All ties were connected to an outside spacer timber with lag screws. Note that this installation is typical of North American bridge installation practice and, in this case, closely follows the practice used by NS, the donor of this particular span.



Figure 1. Bridge Tie Test on 55.5-foot Girder Span at FAST

At FAST, the ties are subjected to 315,000-pound HAL gondolas operating bi-directionally at 40 mph. The Douglas fir glulam ties have accumulated over 900 MGT of HAL traffic to date while the FFU ties were installed later and have 180 less MGT (i.e., 720 MGT to date) than both the control and glulam ties. Vertical deflection measurements were taken at mid-tie and at each rail seat under normal FAST train operations. Figure 2 shows the reference frame under the span at FAST.

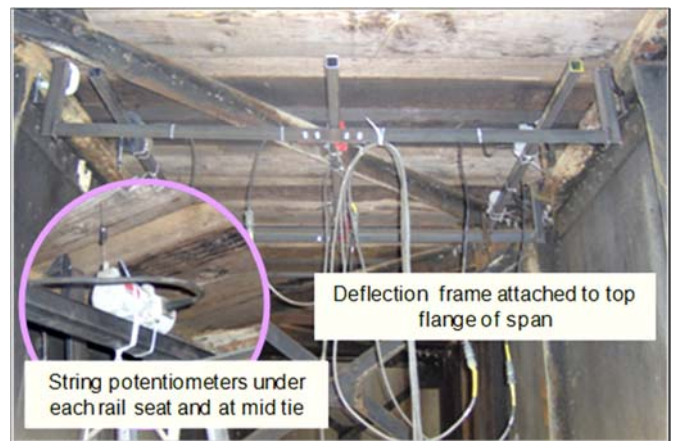


Figure 2. Reference Frame for Measuring Tie Deflections at FAST

Figure 3 shows the average deflection values at the center of the tie for various levels of MGT and for several types of ties; namely, southern yellow pine, Douglas fir, white oak, Douglas fir glulam, and FFU. Note that the white oak was not included in the latest measurements. These deflections are all within the recommended limit for alternative ties on a bridge. This limit was obtained by taking the span length (8 feet) divided by 250, as suggested by AREMA Chapter 7,⁴ resulting in a limit of 0.38 inch. The Douglas fir glulam ties are slightly stiffer than the white oak. The FFU ties behave similar to, but are slightly less stiff than, the southern yellow pine ties. The Douglas fir glulam ties have similar deflections to the Douglas

fir solid sawn timber ties. The deflection values measured at FAST represent the same overall trend as measurements taken in a laboratory test.^{2,3}

Figure 4 shows tie deflections measured at FAST and in the laboratory for a FFU tie beneath both rail seats (inside and outside), as well as at the center of the tie. Note that the aforementioned recommended maximum deflection for the center of tie (0.38 inch) applies and is designated by the green bar in the figure.

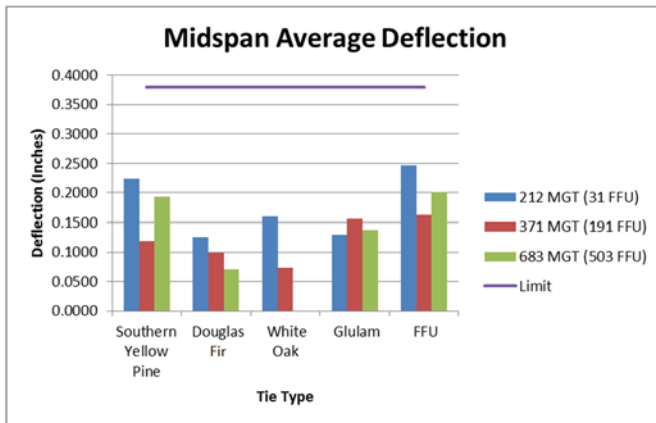


Figure 3. Average Mid-Span Deflection of Various Solid-Sawn Timber and Alternative Ties at FAST

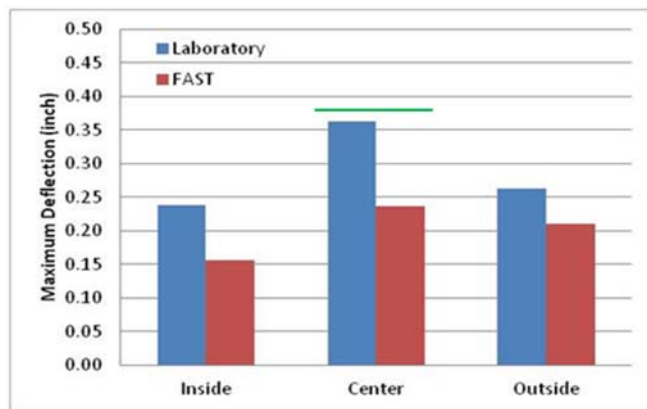


Figure 4. FFU Tie Laboratory versus FAST Mid-Span Deflections

For the laboratory testing, a 27,000-pound load was applied to 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 15.⁴ 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 rail loads to ties has not been measured on the FAST steel bridge. Note that the tie remained below 0.38 inch of deflection in all cases. The laboratory test load and design distribution seem reasonable in

light of these test results. These tests are similar to tests previously conducted on timber ties.⁵ The FFU tie deflections are most similar to those of the southern yellow pine.

TESTING IN REVENUE SERVICE

A long-term evaluation of the FFU bridge ties at the eastern mega site has been ongoing since late 2011. The eastern mega site is located on NS's Virginia Division near Princeton, West Virginia. The ties were installed on a 67-foot riveted steel deck plate girder span with 6.5-foot girder spacing (Figure 5), which is located on a mainline that receives an estimated 26 MGT of traffic annually. Operating speeds on this heavy-haul coal route are typically between 15 and 25 mph over grades as steep as 1.4 percent in some areas. To date, no maintenance has been required for these ties.



Figure 5. Bridge Tie Test on 67-foot Girder Span at the Eastern Mega Site

Annually, gage-strength measurements are conducted by applying lateral loads ranging from 2,000 pounds to 9,000 pounds to the head and base of the rail using a lateral track loading fixture (LTLF). Figure 6 shows a comparison of the maximum lateral deflections of the rail under static loads on the FFU ties, categorized by MGT. Measurements were taken periodically at the same nine ties throughout the bridge span. The deflections are all well within acceptable limits; total gage widening within 5/8 inch when applied lateral force is increased from 0 to 4,000 pounds is seen as acceptable by FRA standards.⁶ It is important to note that the last measurement (i.e., the second 0-kip measure) represents the residual change in gage widening after the loads were applied and removed.

In addition to the gage-strength measurements with the LTLF, vertical deflections taken at the mid-tie as well as at each rail seat were collected under dynamic loads of revenue service operations. Data was collected on two ties near the center of the span under multiple train passes, including trains containing 286,000-pound loaded coal cars. Figure 7 shows the results under two loaded coal trains taken in 2013. This figure presents the maximum vertical deflection of one of the test ties under the following train passes: a 19,773-ton train with 140 loaded coal cars (Number 1) and a 14,247-ton train with 100 loaded coal cars (Number 2).

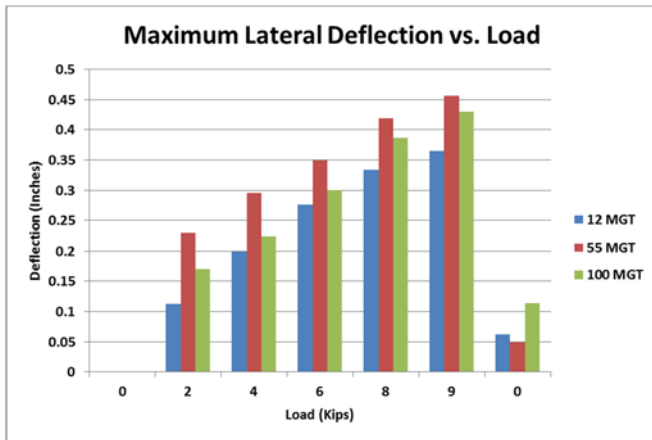


Figure 6. Maximum Lateral Deflection of the Rail under Load

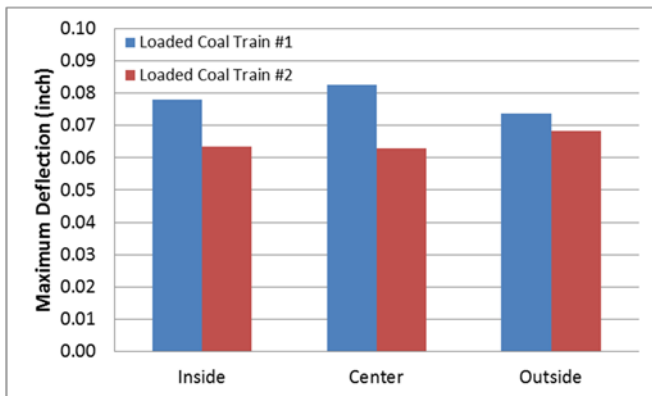


Figure 7. FFU Mid-Span Deflections under Two Coal Trains in Revenue Service

The maximum mid-tie deflections are well below the 0.31-inch limit recommended by AREMA. These values are much lower than those observed at FAST for two obvious reasons. First, the girder spacing differs between the two bridges (i.e., NS bridge girder spacing is only 6.5 feet whereas the span at FAST is 8 feet). This difference in girder spacing results in a much smaller bending moment (approximately half) for the bridge at the eastern mega site than the one at FAST. Second, the axle loads for the loaded coal trains are about 10 percent lighter than the train being run on the High Tonnage Loop at FAST. Based on this information, the resulting vertical deflections are in line with these estimates.

FUTURE TESTING

The performance of the test ties will continue to be monitored for a period to be determined at FAST and at the eastern mega site. Ideally, bridge deck ties should last for thousands of MGT of traffic. Subject to tie condition and other test requirements, TTCI anticipates that the tests will continue for several years.

The ties at both locations will be visually inspected on a regular basis for condition and their performance observed/measured periodically under traffic. The failure criteria noted under laboratory 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.

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