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Evaluation of Alternative Bridge Ties and Hardware

David Linkowski, Duane Otter, and Anna M. Rakoczy

Key Findings:

- Douglas fir glulam ties have accumulated more than 1,562 MGT of HAL traffic to date at FAST with no maintenance required.
- The FFU ties have accumulated more than 1,382 MGT of HAL traffic at FAST with no maintenance required.
- No cracking has been noted in the FFU ties and only minor cracking has been noted in the glulam ties. This includes the ties' survival of the 2016 derailment at FAST.
- Comparatively, most of the solid-sawn ties did not survive the derailment.
- Superelevated glulam ties have accumulated 433 MGT of HAL traffic at FAST with no maintenance required.
- Glulam and FFU ties continue to show no signs of the warp or twist observed in the previous solid-sawn ties.
- Quick-Set[®] hook bolts have accumulated 582 MGT with normal maintenance required and four broken bolts replaced.

[Transportation Technology Center, Inc. \(TTCI\)](#) has been investigating alternatives to solid-sawn timber ties for open deck bridges since 2009 at the Facility for Accelerated Service Testing (FAST). Long-term performance is being evaluated for two alternative bridge tie types that met recommendations based on laboratory testing; namely, Douglas fir glued-laminated (glulam) timber ties and fiber-reinforced foamed urethane (FFU) ties. Engineered open deck bridge ties, including glulam and FFU ties continue to perform well at FAST. This work is of the Association of American Railroads' (AAR) Strategic Research Initiatives program. FAST is located at the Federal Railroad Administration's Transportation Technology Center, Pueblo, CO.

In 2016, a derailment occurred at FAST—the event destroyed the deck of the FAST East Steel Bridge with the original solid-sawn timber ties, i.e., Douglas fir, white oak, and southern yellow pine (SYP), which had served as the control ties for the test. In the replacement deck, one span was furnished with Quick-Set[®] hook bolt fasteners. The FFU and glulam ties on the bridge survived the derailment and were reinstalled to continue testing.

In 2017, TTCI replaced the eastmost, 30-foot concrete box girder on the middle bridge with a steel deck plate girder (DPG) span. The span was installed as an open deck; however, the middle bridge is located in a 5-degree curve with 4 inches of superelevation. To provide for the superelevation, Union Pacific Railroad (UP) donated a unique set of Douglas fir glulam ties with the required superelevation cut directly into the ties themselves. These ties have been added to alternative bridge tie test at FAST.

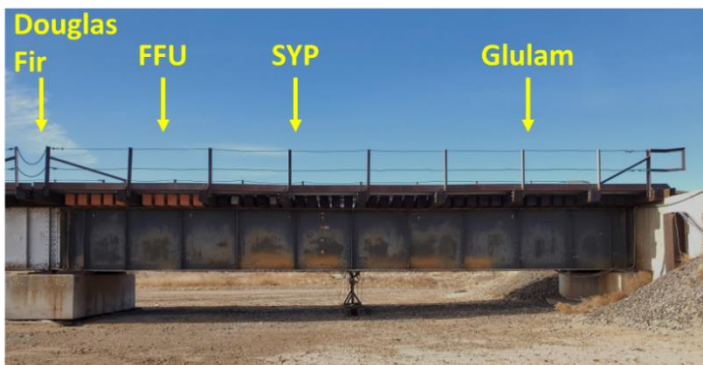
Results to date have been encouraging regarding alternative bridge deck ties and hardware, with testing under heavy axle loads (HAL) currently ongoing for both the glulam ties (normal and superelevated) and the FFU ties.

Prior to field installation, each tie type underwent laboratory tests to evaluate structural properties. Lab testing of the FFU ties also included spike pull-out resistance and gage-widening resistance. The laboratory testing was followed by installing the glulam, SYP, and FFU ties on the 55-foot riveted steel deck plate girder test span at FAST.^{3,4} 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 location for structural bridge ties.

Table 1 provides dimensions for all ties in test. Figure 1 shows the location of test ties on the FAST East Steel Bridge. The superelevated glulam ties are on a separate span.

Table 1. Dimensions of tested ties

Tie Type	Height	Width	Length	Tie span center-to-center of girders
Southern yellow pine	12"	10"	12'	8'
Douglas fir	9.75"	9.75"	12'	6.5'
FFU ties	12"	10"	12'	8'
Douglas fir glulam	12"	10.75"	12'	8'
Superelevated glulam	9 – 14.25"	10.75"	12'	7'

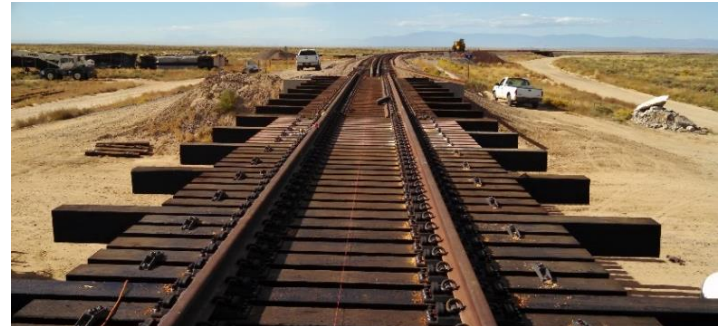

Figure 1. Locations of test tie types on the East Steel Bridge at FAST

Sekisui Chemical Co., Ltd. of Japan produces an FFU crosstie for open deck bridges. In 2011, the company donated ties for testing on the steel bridges at FAST. The bottoms of the ties were milled to allow a gap for rivets on the top flange.² The ties survived the derailment at FAST in 2016 in which they supported a derailed wheel in the 55-foot open deck DPG span. The FFU ties had minor, superficial damage from the wheel flange; whereas, the adjacent ties were shattered at point of impact. After the bridge deck was repaired, the FFU ties were reinstalled and currently have accumulated over 1,382 MGT of traffic at FAST.

In 2009, UP donated Douglas fir glulam ties for testing. The UP has used glulam timbers since the 1990s to replace timber bridge stringers—a practice initiated by predecessor Southern Pacific Railroad.¹ Only in the past few years has glulam timber commonly been used for deck ties on a bridge. The current glulam ties on the 55-foot span at FAST also survived the 2016 derailment with all damage limited to the top sacrificial laminate. The ties were flipped upside down and reinstalled in the new deck.⁷ To date, these ties have accumulated 1,562 MGT with no maintenance.

Additionally, when the deck of the East Steel Bridge was reconstructed after the derailment, new hardware was implemented for the testing of next generation bridge decks. The

bridge deck ties were furnished with two types of Loadmaster™ plates: 10"× 27" and 8.2"× 21.5". On the 55-foot span, the ties were fastened to the deck with Quick-Set® hook bolts. Figure 2 shows the deck rebuild after the derailment.


Figure 2. East Steel Bridge deck rebuild after 2016 derailment

In late 2017, a 30-foot, pre-stressed, concrete box-girder span was replaced with a steel DPG span with open deck. The span is located in a 5-degree curve with 4 inches of superelevation. UP donated a set of Douglas fir glulam ties with the appropriate superelevation cut into the ties themselves. To date, these ties have accumulated 433 MGT of HAL traffic at FAST.

The superelevated ties were also fastened to their span via Quick-Set® hook bolts where possible. Figure 3 shows the tie cross section with the superelevation cut.


Figure 3. Superelevated glulam ties installed on a 30-foot DPG span in the State of the Art (SOA) Bridge at FAST

This is a severe test of the capabilities of the Quick-Set® hook-bolt system as the ties have no daps and the top flanges of the DPG are smooth. The hook bolts and friction are the only restraint to lateral movement of the ties on this span.

TEST SETUP

During FAST operations, ties are subjected to 315,000-pound HAL gondolas operating bi-directionally at 40 mph. Vertical deflection measurements were taken at mid-tie and at each rail

seat under normal FAST train operations. Two of each type of tie were instrumented for the test. These deflections were taken with respect to the ties' respective spans.

The FFU and glulam ties were installed on the 55-foot DPG span of the East Steel Bridge in two 5-tie panels separated by one 18-foot-long walkway tie. The two tie types are separated by 19 SYP ties. The 65-foot DPG span of the East Steel Bridge was furnished entirely with the control Douglas fir ties (Figure 1).

It should be noted that the 55-foot DPG span of the East Steel Bridge has a girder center-to-center spacing of 8 feet; whereas the 65-foot span has a center-to-center spacing of 6.5 feet. As a result, it is expected the Douglas fir ties will experience more bearing and less bending force upon loading compared to the FFU and glulam test ties on the 55-foot span.

The deck of the 30-foot DPG span was constructed entirely of the superelevated glulam ties. This span was installed in the State of the Art (SOA) Bridge at FAST, replacing a 29' 10" concrete box girder span on the east end. Though it is of an open deck design, it sits adjacent to a 42-foot concrete box girder span with a ballasted deck. The center-to-center girder spacing of the 30-foot span is 7 feet.

RESULTS

Deflection measurements were taken under regular FAST train operations with 10 laps of data collected in each direction. Figure 4 plots the average vertical displacement at the tie center. The figure also shows tonnage accumulated by the ties at the time the measurements were taken.

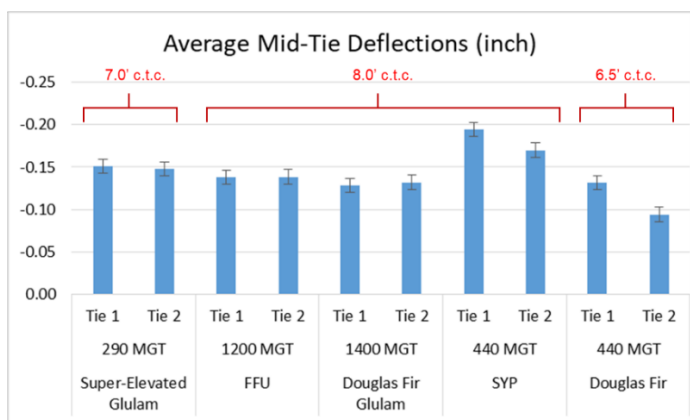


Figure 4. Average middle tie deflection for each tie type.

The ties with the largest center deflection were the SYP ties with an average of approximately 0.18 inch. The ties with the least center deflection were the Douglas fir glulam with an average of 0.13 inch. The solid-sawn Douglas fir ties also had an average center deflection of just over 0.13 inch; however, it is important to note that the solid-sawn Douglas fir ties were installed on the

65-foot span with a shorter center-to-center spacing of the girders thereby providing less of a bending moment for the ties. These ties are also newly installed, with only 582 MGT. The FFU ties had an average center deflection of 0.138 inch, and the superelevated glulam ties an average deflection of 0.145 inch.

Looking at a cumulative distribution function (CDF) plot (Figure 5) of the tie deflections, the differences between the tie types are significant. Though the Douglas fir ties had some of the lowest deflection values of the ties tested, there was higher variability in the data as indicated by the steps in the plot.

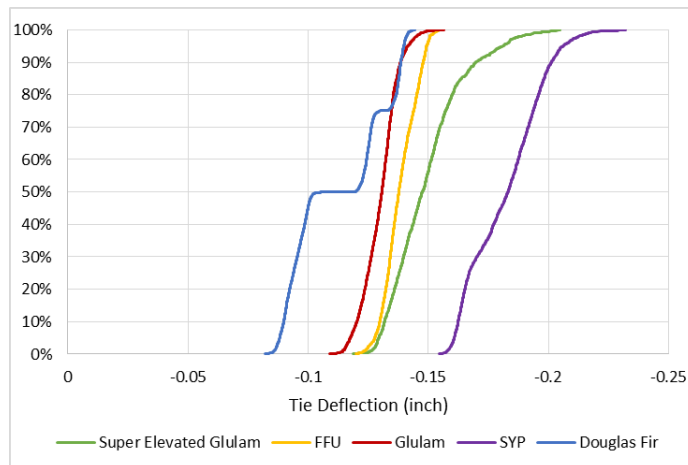


Figure 5. CDF plot of tie deflections

This is also indicated by the slight hump in the plot lines of the SYP ties. The glulam and the FFU ties had the least variability of the group. The superelevated glulam tie deflections are spread out similar to the SYP ties, however, this may reflect differences in track geometry.

A difference can also be seen between engineered ties and solid-sawn ties in this test. Differences in the center deflection values become more apparent when looking at a standard deviation plot of the center tie deflections (Figure 6).

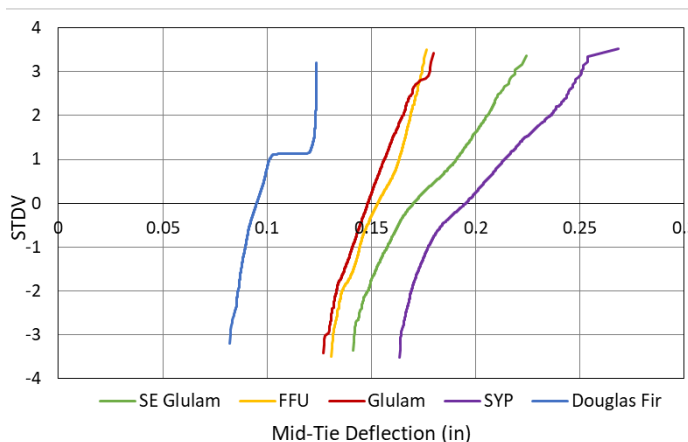


Figure 6. Standard deviation plot of tie deflections

Here, less variability is seen in the deflection of engineered ties (i.e., glulam and FFU ties) compared to the solid-sawn ties. It should be noted that none of the ties deflected close to the American Railway Engineering and Maintenance-of-Way Association (AREMA) Chapter 7 recommended limit of 0.38 inch for an 8-foot span.⁵

IN-TRACK PERFORMANCE OF DECK HARDWARE

For the 30- and 55-foot spans, TTCI fastened the ties to the top flange of the steel girder using Quick-Set[®] hook bolts. This includes the superelevated glulam ties. The lateral forces of the track are restrained only by the surface friction of the tie-to-top flange interface and the hook bolts. Witness marks were painted during the installation of these ties to track any outward, lateral movement of the track. Regular observations of these marks indicate little to no lateral migration of the superelevated ties across the girders.

Quick-Set[®] hook bolts have required little attention so far in-track. Due to dynamic effects, they will sometimes shift longitudinally, causing them to be angled slightly. In addition, three out of 20 Quick-Set[®] hook bolts on the 5-degree curve broke during 395 MGT, while one of 32 Quick-Set[®] hook bolts on a tangent span broke after 543 MGT. Traditional hook bolts have also broken in service at FAST. Investigation into these failures continues. Track crews noted the ease of installation using the Quick-Set[®] hook bolts, as opposed to more traditional hook bolts, indicating ease of access as well as the lack of drilling through the deck ties as two positive characteristics.

CONCLUSION

Engineered open deck bridge ties, including glulam timber ties and FFU ties continue to perform well at FAST. The Douglas fir glulam ties have accumulated more than 1,562 MGT of HAL traffic in 10 years of service at FAST with no maintenance required. The FFU ties at FAST have accumulated more than 1,382 MGT of HAL traffic in 9 years with no maintenance required. More recently installed superelevated glulam ties have accumulated 433 MGT on an open deck steel DPG span in a 5-degree curve with 4 inches of superelevation. The glulam and

the FFU ties continue to show no signs of warp or twist as observed in the previous solid-sawn ties. In FAST operations, Quick-Set[®] hook bolts have accumulated 582 MGT. Plans call for continued testing and tonnage accumulation at FAST for all of these open deck bridge components.

References

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For comments or questions about this publication, contact [David Linkowski@aar.com](mailto:David.Linkowski@aar.com)

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