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Evaluation of Polymer Composite Tie Lateral Track Resistance at FAST

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Summary

Lateral track strength provided by engineered polymer composite (EPC) ties has shown to be similar to or higher than that of control hardwood ties according to ongoing research by Transportation Technology Center, Inc. (TTCI). TTCI is conducting research on modern composite ties to evaluate their performance and to improve EPC design guidelines and recommendations.

This *Technology Digest* presents data and TTCI researchers' observations on the lateral resistance provided by EPC ties in ballasted track at the Facility for Accelerated Service Testing (FAST) near Pueblo, CO. Three EPC tie designs and mixed hardwood control ties were evaluated using single-tie push (STP) testing, which measures the resistance provided by a single tie when pushed laterally through the ballast. Testing was conducted immediately after installation at 0 MGT, and after approximately 13 MGT of accumulated tonnage.

Results of this study show:

- A wide range of surface texture depth and roughness has been observed for all three EPC tie types — even within samples from the same suppliers.
- At 0 MGT, two composite tie types showed lateral resistances higher than wood ties. One EPC tie design with relatively smoother texturing showed lower lateral resistance forces compared to wood ties at 0 MGT.
- At 13 MGT, EPC ties showed similar or higher lateral resistance compared to the wood control ties.
- Sufficiently textured EPC ties can exceed the lateral resistance provided by control wood ties immediately after installation (0 MGT) and after 13 MGT of tonnage accumulation.

Key recommendations resulting from this and previous work include:

- Composite ties, with surfaces that otherwise may be smooth and have low ballast-tie friction, should be textured on both the sides and bottom to increase lateral restraint.
- Surface texturing should be consistent and verified as part of manufacturing quality control
- Surface texturing (on otherwise smooth tie bottoms and sides) between 1/8 and 1/4 inch depth, sized and spaced approximately equal to the size of a nominal ballast particle (1-2 inches) has been shown to provide sufficient ballast-tie friction during STP testing.

Composite ties offer a potential alternative to creosote-treated wood ties; particularly in areas of high rot or high decay. As part of a broader evaluation of composite tie performance including laboratory testing, modeling, and in-track testing at FAST, EPC ties are also being evaluated in revenue service on a Class I railroad. TTCI is working closely with AREMA Committee 30 to implement findings of this work in AREMA's *Manual for Railway Engineering*.

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INTRODUCTION

Transportation Technology Center, Inc. (TTCI) is conducting research on Engineered Polymer Composite (EPC) tie and fastener systems as an alternative for wood crossties. This work is part of an ongoing AAR Strategic Research Initiatives project to improve design and testing guidelines for composite ties in AREMA's *Manual for Railway Engineering*, Chapter 30 – Ties.

Ties and fasteners act together as a system to transfer vertical and lateral load applied on the track into the ballast, and to maintain sufficient track geometry. Over 90 percent of Class I railroad track miles use wood crossties. In areas prone to rot and decay, wood ties may remain serviceable for less than 10 years before replacement is necessary — often due to plate cutting and loss of gage strength. These types of environments present an opportunity for an alternative tie that may offer a longer lifecycle with similar performance. The railroad industry seeks to further the development of EPC ties as an alternative for wood crossties.

An important performance property of a crosstie is its ability to provide lateral track resistance when embedded in ballast. This *Technology Digest* discusses the establishment of new EPC tie test zones at the Facility for Accelerated Service Testing (FAST), as well as the results from TTCI's evaluation of EPC tie lateral resistance compared to conventional hardwood ties.

BACKGROUND

EPC ties are the most common type of composite ties in the industry, but they account for less than 1 percent of crosstie purchases. Polymer composite ties are generally composed of post-consumer recycled plastic. Additives and fillers and fiber or particle reinforcement may be added to enhance specific properties.[1]

Polymer composite ties have been in development in the U.S. since the mid-1990s.[2] One Class I railroad has reported over 1 million composite ties installed on their system. Historically, EPC tie performance has been inconsistent with examples of composite ties performing well at FAST.[3]

LATERAL TRACK RESISTANCE

A key function of a crosstie in ballasted track is to provide lateral restraint of the track structure. Wheel-rail forces and thermal stresses in continuously welded rail track produce lateral forces that act to shift the track out of alignment. These lateral forces are resisted by the summation of individual tie-ballast interactions on tie's sides, bottoms, and ends over a length of track.[4]

Lateral restraint is dependent on many variables including ballast type, ballast gradation, ballast shoulder profile, tie geometry, tie material, weight and surface texturing, tamping and installation procedures, and tonnage accumulation. Low lateral track strength can lead to geometry misalignments and, in severe cases, track buckling and derailments.[5] Track lateral resistance for all tie types is generally lowest after initial installation and tamping.[4] Dynamic track stabilization and/or slow ordered through traffic are often used after the ballast is disturbed (e.g., after track surfacing and tamping) to restore lateral track strength for normal operations.[4]

Composite ties need to provide similar or improved lateral track strength in order to be a viable alternative to wood ties. It was observed early in the development of composite ties that surface texturing was necessary to sufficiently increase the lateral resistance of polymer composite ties to that of wood ties.[6]

All EPC tie designs generally include some form of surface friction modification; either by stamping, embossing, or molding of notches/patterns, or a roughened surface on the sides and bottom of the tie.

TEST SETUP

Polymer composite ties from three major suppliers were selected from railroad and supplier inventory for inclusion in this study. Samples were composed of ties randomly selected by TTCI test engineers and produced over at least three different months of production. As ties were selected from inventory, all had passed through their respective suppliers' quality control procedures in place at the time. One hundred ties were randomly selected from each supplier for installation at FAST in continuous test zones. New mixed hardwood ties representative of Class I tie species and grades were also installed as a control zone.

Table 1. Tie types Tested for the Center Bending Study

Tie Type	Notes
EPC Tie Type A	Random selection of production between 2014 and 2015
EPC Tie Type B	Random selection of production between 2014 and 2015
EPC Tie Type C	Random selection of production between Dec. 2015 & Feb. 2016
Mixed Hardwood Control	Random selection of new southern mixed hardwood ties used at FAST

The EPC tie and fastener test zones and the mixed hardwood control zone are installed in Section 25 of the High Tonnage Loop at FAST. Section 25 is a 6-degree curve with 5 inches of superelevation. Track geometry in Section 25 is maintained to FRA Class 4 standards.

Each of the four test zones in Table 1 were installed using an out-of-face procedure. Mainline Class I granite ballast, conforming to AREMA 4a gradation, was used.

Figure 1 shows an EPC tie test zone prior to ballast dumping and surfacing. The surface texturing along the tie sides is visible.

Figure 1. Skeletonized EPC Tie Zone during Installation before Ballast Dumping. Note Texturing on Sides of Ties

Figure 2 shows typical surface textures on the sides of each tie type and the average weight of the EPC test ties (8-foot, 6-inch-long tie with a nominal 7-inch by 9-inch cross section). The mixed hardwood control ties had the same length and cross section and averaged 195 pounds.

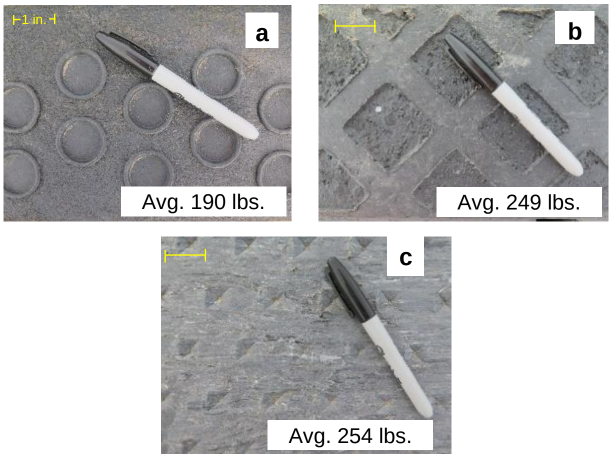

Figure 2. Representative Bottom and Side Surface Texturing and Average Weights (8-foot, 6-inch tie) for EPC Ties

Tie types A and B had texturing approximately 1/4 inch in depth, with pattern shapes and spacing similar to the size of a nominal ballast particle (1 to 2 inches). Tie type C had dimples less than 1/8 inch in depth and about 3/4 inch square in size. The lateral resistance of the three EPC tie designs were evaluated and compared to the hardwood control ties. Qualitative observations were documented on the roughness and variability of surface texture for each tie type.

SINGLE TIE PUSH TESTING

Single tie push (STP) testing was conducted on a sample of EPC and mixed hardwood ties at 0 MGT immediately after installation, and again after approximately 13 MGT of tonnage accumulation. Tests were performed according to Test 8 in the AREMA Manual, Chapter 30, Part 2.[1] Twenty ties from each EPC zone and from the mixed hardwood control zone were tested. Variability seen in previous STP tests dictated the relatively large sample size per zone. Weather conditions were dry and the ballast had no observable moisture.

For the STP test, the inside rail is used as a reaction frame to push the tie laterally using a camming fixture attached to a hydraulic ram. Load is applied at a rate of approximately 2,000 pounds per second to the tie until 2 inches of lateral displacement is observed, a maximum load of 10,000 pounds is reached, or the tie has “floated” up and contacts either rail. Following the test, the tie is reinstalled and tamped. Applied force and tie displacement are recorded throughout the test. STP results provide a relative indication of a tie design’s lateral resistance to movement in ballast. Figure 3 shows the STP test fixture and setup.

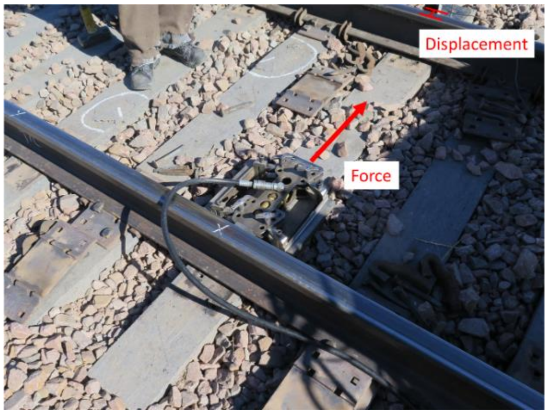

Figure 3. STP Test Fixture and Setup

RESULTS AND CONCLUSIONS

Because STP tests were conducted at 0 MGT immediately after tamping and with no dynamic stabilization, results likely represent the lower bounds of lateral resistance — an important property for track stability under initial train passes. Figure 4 shows the STP force versus displacement curves for the four tie types at 0 MGT and 13 MGT.

Specific recommendations on the interpretation of STP test data is not provided in the description of Test 8; however, STP forces are generally interpreted at or between 1/4 and 1/2 inch of lateral displacement. This is often where the highest lateral force is observed; particularly for wood and composite ties where a distinct peak may not be visible. Figure 5 shows a boxplot of the STP force at 1/4 inch of lateral displacement for the four tie types at 0 and 13 MGT.

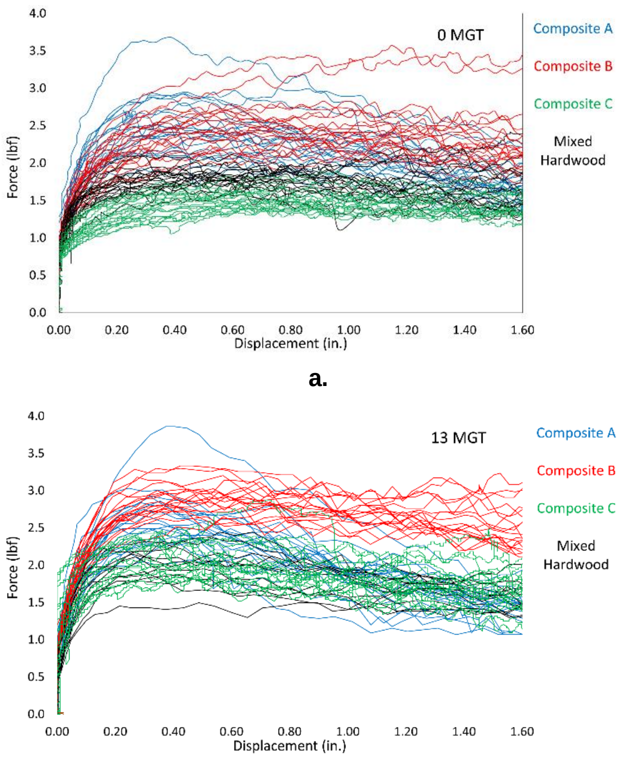

Figure 4. STP Load vs. Deflection Curves for the Four Tie Types at (a) 0 MGT and (b) 13 MGT Test Intervals

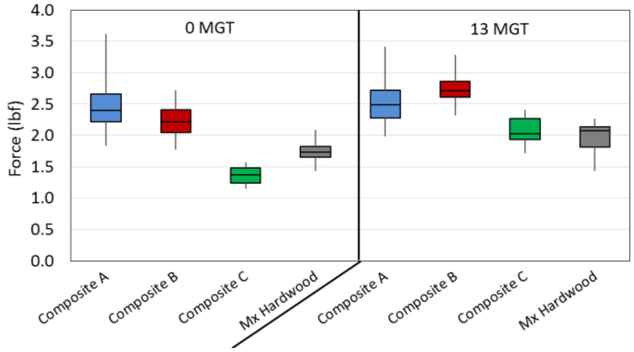

Figure 5. Boxplots of the Applied Force at 0.25 inch of Displacement for the Four Tie Types at 0 and 13 MGT

Observations showed a wide range of surface texture roughness and consistency on the EPC ties tested indicating variability in the manufacturing process. This variability is a contributor to the variability of STP test results within each tie type.

Results show that two of the EPC tie types (A and B) had higher lateral resistance at both 0 and 13 MGT compared to the wood ties. EPC tie type C (which had a noticeably smoother surface texturing) had lower lateral resistance than wood ties at 0 MGT, but had similar results to the wood tie zone at 13 MGT. Conventional industry knowledge would suggest that wood tie lateral resistance would increase by accumulating 13 MGT of tonnage. This, generally, was not observed. It is possible that additional tonnage would be needed to observe this increase. Surface texturing on composite ties has not been shown to deteriorate over the course of a recent test of EPC ties at FAST.[3]

Key recommendations resulting from this study include:

- EPC ties with smooth surfaces that may otherwise have low ballast-tie friction should be textured on both sides and the bottom to increase lateral restraint.
- Surface texturing (on otherwise smooth tie bottoms and sides) between 1/8 and 1/4 inch depth, sized and spaced approximately equal to the size of a nominal ballast particle (1 to 2 inches) has been shown to provide sufficient ballast-tie friction during STP testing.
- Texturing should be consistently rough and should be verified during manufacturing quality control.

Acknowledgement

TTCI appreciates the continued input from AREMA Committee 30 Subcommittee 6 - Composite Ties, as well ongoing support and guidance provided by the Tie and Fastener Technical Advisory Group.

References

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