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Evaluation of Engineered Polymer Composite Ties at FAST

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Summary

Researchers at Transportation Technology Center, Inc. (TTCI) are evaluating the performance of engineered polymer composite (EPC) ties and are working to improve design guidelines and recommendations. As presented in this interim update, two primary failure modes have been observed on EPC ties during initial in-track testing (77 MGT in one zone and 218 MGT in other two zones); namely, spike hole cracking and fatigue cracking in the center of ties.

On-track testing is being conducted at the Facility for Accelerated Service Testing (FAST), Pueblo, Colorado, for three EPC tie designs installed with two different fastening systems. Results thus far focus on the failure modes that have been observed and the improved recommendations and testing guidelines for EPC ties being proposed based on these results.

To date, one EPC tie type has shown no center cracking, but six ties have spike hole crack failures. A second EPC tie type has shown no spike hole cracking, but a 10 ties have center cracked. The third EPC tie type has had 27 ties fail through center cracking and spike hole cracking. Of the 300 total EPC ties installed, 43 have failed to date. Spike hole cracking has occurred in two of the tie designs despite pre-drilling. Results are being used to develop two new laboratory tests to better understand the performance of EPC ties under realistic cyclic loading.

The following testing recommendations are currently being developed for the AREMA *Manual for Railway Engineering*:

- A cyclic bending fatigue test, simulating in-track bending loads is needed to assess the bending performance of EPC ties under repeated loads, and
- A modified version of AREMA Test 6 (tie and fastener wear/abrasion test) is needed to exercise rail seat bending and spike hole stresses under repeated loads.

Gage widening caused by thermal expansion and thermal gradient-induced bending has also been observed consistently in all three EPC tie zones. Approximately 0.2 inch of gage increase was observed at FAST on a late summer day (for a top surface tie temperature delta of about 95 degrees). Further study is needed to understand the thermal effects on track gage and the classes of track for which EPC ties are suitable.

Composite ties offer a potential alternative to creosote treated wood ties, particularly in areas of high rot or high decay. TTCI is working closely with AREMA Committee 30 to implement findings of ongoing EPC tie research into industry best practices.

These tests, part of ongoing work funded by the AAR Strategic Research Initiative (SRI) program, will provide improved assessment tools to better optimize and improve EPC tie materials and designs because they will impart more realistic loading conditions and exercise known failure modes: tie center cracking and spike hole cracking.



INTRODUCTION

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 SRI project to improve design and testing guidelines for composite ties in AREMA Chapter 30 – Ties.¹

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 utilize 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.

This *Technology Digest* presents a brief history of the in-track performance of EPC ties, the establishment of a new EPC tie test, results of initial testing, and recommendations based on these results.

BACKGROUND

Engineered polymer composite (EPC) ties are the most common type of composite ties, but account for less than one percent of the crosstie market in the U.S. Polymer composite ties are generally composed of post-consumer recycled plastic. Additives, 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, with a history of inconsistent performance. Railroads have observed center cracking, rail seat cracking, and spike hole cracking on EPC ties in service; as well as cracking of ties during unloading and installation. While a select set composite tie test zones have performed well both in revenue service and at the

Facility for Accelerated Service Testing (FAST), improved testing guidelines and recommendations are needed to ensure more reliable performance.^{3,4,5}

IN-TRACK TESTING AT FAST

In 2015 and 2016, EPC ties from three major suppliers were selected from inventory for inclusion in this study. Samples were composed of ties randomly selected by TTCI test engineers to provide a representative sample of ties produced over at least three different months of production. The ties had all passed through their respective suppliers’ quality control procedures and were documented to have met all applicable AREMA recommended criteria. 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 installed as a control zone. EPC Tie Type A and C zones were installed in the summer of 2015 and the EPC Tie Type B zone in the summer of 2016.

Half of the 100 ties in each zone were outfitted with 14-inch AREMA plates and standard 5/8-inch cut spikes (the most common fastening system in use). The other half used 18-inch Pandrol VICTOR plates with 15/16-inch Evergrip® double-headed drive spikes. Table 1 lists the layout of the four test zones that were evaluated and the pre-drill size used during installation. A 1/2-inch predrill was used for the cut spikes as difficulty driving was encountered with a 3/8-inch pre-drill. The polymer composite tie and fastener test zones, and mixed hardwood control zone are installed in Section 25 FAST’s High Tonnage Loop — a 6-degree curve with 5 inches of superelevation. Heavy axle load tonnage was accumulated with a train of 315,000-pound (39-ton axle load) coal cars. The FAST train operates at 40 mph, approximately a 2-inch overbalanced speed for the curve, which helped to accelerate component wear; particularly on the high rail. Track geometry in Section 25 is maintained to FRA Class 4 track safety standards.

Table 1. EPC Tie and Fastening System Test Zones in Section 25 at FAST

Tie Type	# Ties	Fastening System	Spike Hole Predrill Size (depth of spike)	Tonnage 5/19/17 (MGT)	Notes
EPC Tie Type A	50	14" AREMA plates and cut spikes	1/2-inch	230	Random sample of production 2014 to 2015
	50	18" Victor plates and drive spikes	11/16-inch		
EPC Tie Type B	50	14" AREMA plates and cut spikes	1/2-inch	230	Random sample of production 2014 to 2015
	50	18" Victor plates and drive spikes	11/16-inch		
EPC Tie Type C	50	14" AREMA plates and cut spikes	1/2-inch	89	Random sample of production Dec. 2015-Feb. 2016
	50	18" Victor plates and drive spikes	11/16-inch		
Mixed Hardwood	50	14" AREMA plates and cut spikes	3/8-inch	230	Control for comparison
	50	18" Victor plates and drive spikes	11/16-inch		

THERMAL EXPANSION — EFFECT ON GAGE

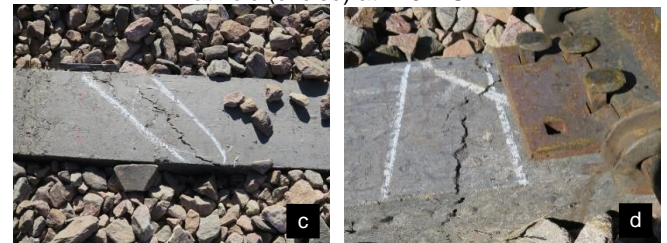
In fall of 2016, track gage measurements in Section 25 were taken at various times throughout the day using the FRA’s T-18 track inspection vehicle. Weather conditions were clear. At the time of each test run, EPC tie temperatures were measured for a sample of each zone at the tops, ends, and sides of each tie. Ambient and rail temperatures were also recorded. Figure 1 shows the gage channel measurement from the coolest tie temperatures recorded at 7:30 AM and the warmest tie temperatures recorded at 2:00 PM. Figure 1 also depicts the general observation that the bottom of the tie tends to remain insulated by the tie itself and the crib ballast, creating a thermal gradient and generating center negative bending. Linear expansion of the tie coupled with this bending resulted in about .2 inch of gage widening, consistent between all three EPC tie zones. No significant gage increase was observed in adjacent wood or concrete tie zones throughout the day.

TIE CENTER AND SPIKE HOLE CRACKING

Failure modes continue to be documented as tonnage is accumulated. Figure 2 shows examples of the two most common failure modes that have been observed: cracking near the center of the tie, and cracking at the spike holes. To date, one EPC tie type has shown no center cracking, but six ties have spike hole crack failures. A second EPC tie type has shown no spike hole cracking, but 10 ties have center cracks. The third EPC tie type has had 27 ties fail as a result of center cracking and spike hole cracking. Of the 300 total EPC ties installed, 43 have failed to date.



Center cracked EPC tie and initiation of crack at void (circled) at 120 MGT



(c) Example of another center crack

(d) Spike hole crack after 12 MGT



(e) and (f) Spike hole cracks in drive spike holes

Figure 2. Failure Modes Observed in New EPC Tie Test Zones

Figure 2(a) indicates a center crack representative of that found on five ties in one of the EPC tie zones. These cracks appear to have initiated at a void/stress riser in the

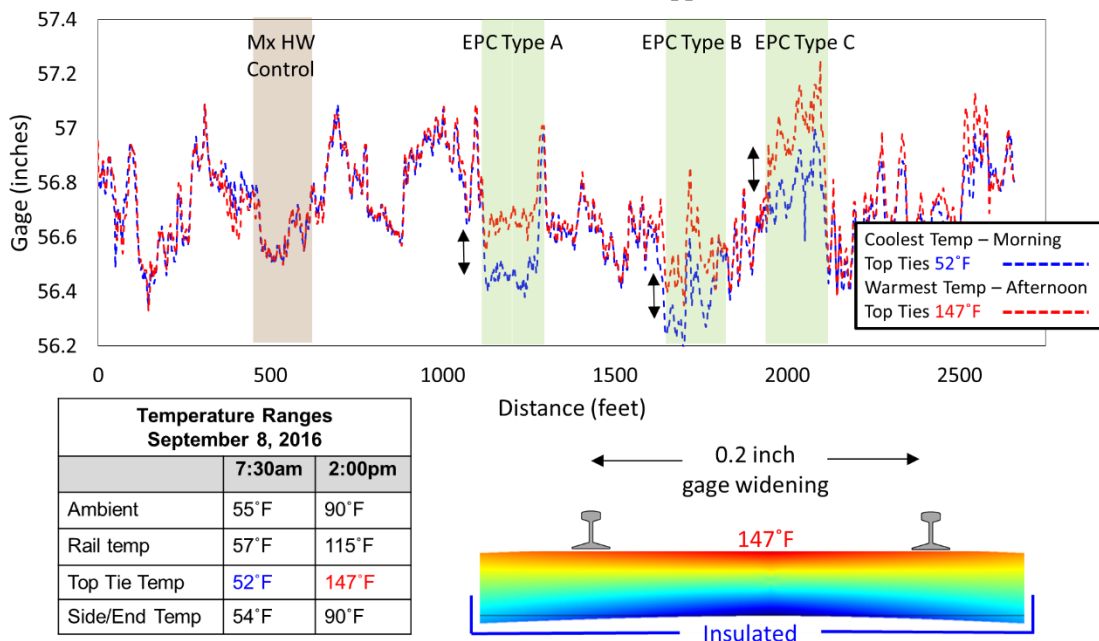


Figure 1. Unloaded Gage Measurements at Two Temperature Extremes Sept. 8, 2016

cross section of the tie and produced striations consistent with fatigue failures. Previous testing and simulations has shown that EPC ties are unlikely to fail in ultimate bending strength once installed in track, but may be susceptible to ultimate failure during installation.^{3,6} The observation of these center cracks after tonnage accumulation suggests that fatigue of EPC ties under train loads needs to be investigated further. The current static three-point bend test (AREMA Test 1C) used to characterize tie modulus of elasticity (MOE) and modulus of rupture (MOR) is not sufficient to indicate bending performance under repeated loading.

Figure 2(f) shows a spike hole crack connecting to an adjacent spike hole beneath the tie plate. Spike hole cracks were generally observed to develop after tonnage accumulation and not immediately after spike installation. Spike hole cracks have not been observed during laboratory spike insertion and pullout testing (AREMA Test 2). This indicates that current testing recommendations do not adequately assess in-track failure modes.¹

Based on the results observed, TTCI is developing two new bending fatigue tests to evaluate composite tie performance under repeated loading (Figure 3). The first will exercise composite tie center bending in a four-point bend setup. The second will modify the current AREMA tie and fastener wear and abrasion test to exercise rail seat bending and the spike hole cracking observed under repeated in-track loading. Each test setup (span lengths and applied load magnitudes) is being guided by NUCARS[®] track model simulations for EPC tie track and in-track strain gage measurements taken on EPC ties. Both of these tests, once established, will serve as enhanced assessment tools for suppliers to develop improved EPC tie designs.



Figure 3. Conceptual Test Setups to Assess EPC Tie (a) center bending fatigue, (b) rail seat/spike hole fatigue

*NUCARS[®] is a registered trademark of TTCI.

CONCLUSIONS AND RECOMMENDATIONS

Unlike wood or concrete ties, engineered polymer composite ties have been shown to significantly expand during temperature increases. Ambient heat during one late summer day at FAST resulted in about 0.2 inch of static gage widening between the morning and the afternoon. Further research is being done to understand the implications of this behavior on track geometry, gage tolerances, and AREMA recommended criteria.

Testing at FAST has identified spike hole cracking and center cracking as two predominant failure modes for EPC ties. To date, 43 of 300 EPC ties installed have failed.

No relationship between EPC tie MOE and in-track performance has been observed.³ MOR, or the ultimate bending strength of the tie, however, can be used to assess high one-time applied loads during installation (insertion and nipping), but has not been shown to be an indicator of fatigue strength. Fatigue testing recommendations are currently in development as current testing methods are not adequate to assess the failure modes common in EPC ties. As new testing guidelines are developed, existing and future suppliers of EPC ties will have more appropriate tools to assess EPC tie designs.

ACKNOWLEDGEMENT

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