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## Performance of Plastic Composite Ties in Revenue Service – Final Report

Rafael Jimenez and Dingqing Li, TTCI  
Russell McDaniel, Norfolk Southern Railway

### Summary

As part of the Heavy Axle Load (HAL) Revenue Service Test Program funded by the Association of American Railroads and the Federal Railroad Administration (FRA), a test was conducted on a 6.8-degree curve at the Norfolk Southern (NS) Railway eastern mega site between Narrows, Virginia, and Bluefield, West Virginia, to evaluate the performance of two types of plastic composite ties from two manufacturers. Installed in November 2004, the test ties were subjected to about 282 million gross tons (MGT) of mostly HAL traffic. In May 2010, NS decided to remove the plastic composite ties from one of the subzones after several were found broken, effectively terminating the test. Following are the final conclusions:

- In general, the plastic composite ties tested were capable of supporting HAL traffic with acceptable performance. There were no problems related to track geometry, gage strength, tie plate cutting, cut spike uplift, or fastening system component failure in the section of track in which the plastic composite ties were installed.
- Plastic composite ties from only one manufacturer broke, suggesting that different material formulations and manufacturing processes may affect the toughness of plastic composite ties.
- Five plastic composite ties from the same manufacturer broke in two during the 282 MGT test. In November 2008, the first broken tie was discovered after 212 MGT. It broke near its center at a void in the plastic composite material. Near the end of the test, four more ties broke along the cut spike plane as a result of the wedging force created as the spikes were inserted into very hard synthetic tie plugging material. The last four broken ties occurred after regaging.
- In April 2009 after about 230 MGT, the entire test curve including the plastic composite test ties was regaged, due to wide gage in the adjacent wood tie spirals of the same curve. The plastic composite ties did not exceed wide gage limits.
- Results from measurements taken with a lateral track loading fixture and the FRA's T-18 gage restraint measurement system test vehicle indicate that although gage strength degradation and gage widening were slightly higher in the plastic composite ties than in the wood ties, the trends were similar to wood ties.
- Plastic composite ties tend to have lower bending stiffness and lower toughness, as compared to wood ties.
- Pilot holes for cut spikes reduced the occurrence of cracks and plastic composite material buildup between the plate and the top of the plastic composite ties during spike insertion.



**INTRODUCTION**

Since 1997, Transportation Technology Center, Inc. (TTCI) has been monitoring the in-track performance of plastic composite ties under HAL traffic on the High Tonnage Loop at Facility for Accelerated Service Testing (FAST). Some of the plastic composite ties tested at FAST have been able to withstand 39-ton axle loads (315,000-pound gross rail load) in out of face (consecutive tie) installations. The objective of the plastic composite tie test at the NS mega site was to evaluate the performance of these ties on an active HAL route under typical track geometry, train handling, and environmental conditions that exist in revenue service, but not at FAST.

**Test Zone at the NS Mega Site**

In November 2004, the plastic tie test zone was installed in a 6.8-degree curve between Narrows, Virginia, and Bluefield, West Virginia. It consisted of three adjacent subzones: two 75-tie plastic test sections with one 75-tie control section of NS standard solid-sawn mixed hardwood ties in between. Table 1 shows the test environment.

**Table 1. Test Environment & Installation of Plastic Composite Tie Test Zone**

Test Zones (75 ties each)	Polywood, Inc.* (7-inch x 9-inch x 9-foot) TieTek, Inc. (7-inch x 9-inch x 9-foot) Solid-sawn mixed hardwood (7-inch x 9-inch x 8.5-foot)
Location	Mile Post N353.6 Track No.1 – Narrows to Bluefield Mainline
Traffic	Primarily 286,000-pound loads at 30 mph maximum speed
Track Geometry	6.8-degree curve 2.5-inch superelevation 0.8% grade 1.3-inch cant deficiency
Fastening System	8-inch x 18-inch NS standard cut spike tie plates
Installation	Out of Face (consecutive ties) Standard wood tie gang equipment (rapid-impact type gang spiker) No pilot holes

**Tie Bending**

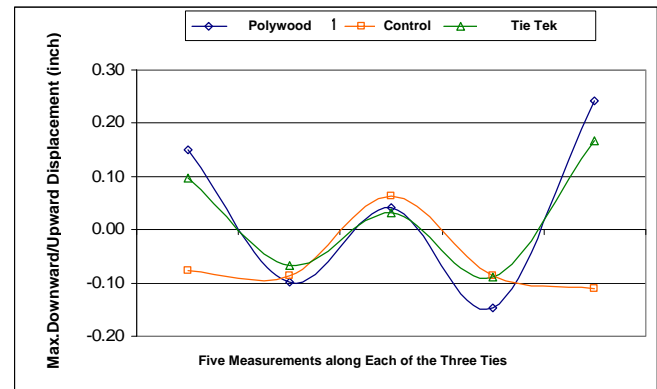
In October 2009, measurements were taken to compare the bending behavior of the plastic composite test ties with the wood control ties under dynamic train loads.<sup>2</sup> Figure 1 shows the measured maximum downward and upward displacement results.

A significant difference between the plastic ties and the wood ties is that the ends of the plastic ties tend to bend upward much more than the wood ties, which is characteristic of the lower bending stiffness of plastic ties as compared to wood ties. Although the plastic ties in both test zones were 6 inches longer than the wood ties in the control zone, where ideally they would have been 3 inches longer on each end, the additional length may not have contributed significantly to the bending profile shown in Figure 1. Many of the ties, both wood and plastic, were not centered in the track.

The results may point to potential long-term problems associated with ballast pumping around the ends of the ties and

\*As of January 2008, the technologies formerly licensed to Polywood, Inc. were and are currently licensed to Axion International. Specific questions about the product should be addressed to Axion International.

large bending stress in the tie plates, which have been observed for some plastic ties evaluated under the program at FAST.<sup>3</sup>



**Figure 1. Vertical Deformation Behavior of Plastic Composite and Wood Ties**

**Track Gage Strength**

Gage strength degradation is gage widening as a function of applied load and accumulated traffic/tonnage.

For the duration of the test (282 MGT), the plastic composite ties continued to perform well relative to gage strength. Figure 2 shows gage strength degradation test results using a lateral track loading fixture (LTLF) for the two plastic tie types tested and the control wood ties. Although the plastic ties tested exhibited slightly higher gage spreading than the wood ties, they exhibited gage strength degradation trends similar to wood ties.<sup>4</sup>

Figure 3 shows the April 2010, final in motion, unloaded track gage measurement taken in the plastic tie and wood tie control test zones using the FRA’s T-18 gage restraint measurement system (GRMS) test vehicle. The result of the final measurement with GRMS indicates slightly higher, but similar gage in the plastic tie zones as compared to the wood tie control zone.

In April 2009, the entire test curve including the plastic test ties was regaged due to wide gage in the adjacent wood tie spirals of the same curve – not due to gage widening of the plastic ties. The regaging procedure used for the plastic ties was basically the same as that used for the wood ties relative to spike removal, spike hole filling using a synthetic material, and respiking. Pilot holes for the cut spikes, however, were drilled at the locations nearest the edge of the ties.

Figure 2 shows the increased gage-spreading strength in the three zones resulting from regaging, which was done after the 208 MGT and before the 235 MGT measurements. Figure 3 shows that one year after regaging, one short section of track in the spiral past the Tie Tek plastic zone exceeded standard track gage by 0.5 inch.

The effect of ambient temperature on the unloaded track gage over a 54°F range (27°F to 81°F) indicated the following maximum changes in gage: Polywood less than 0.5 inch; TieTek about 0.24 inch; and wood ties about 0.16 inch, as measured by NS.<sup>1</sup>

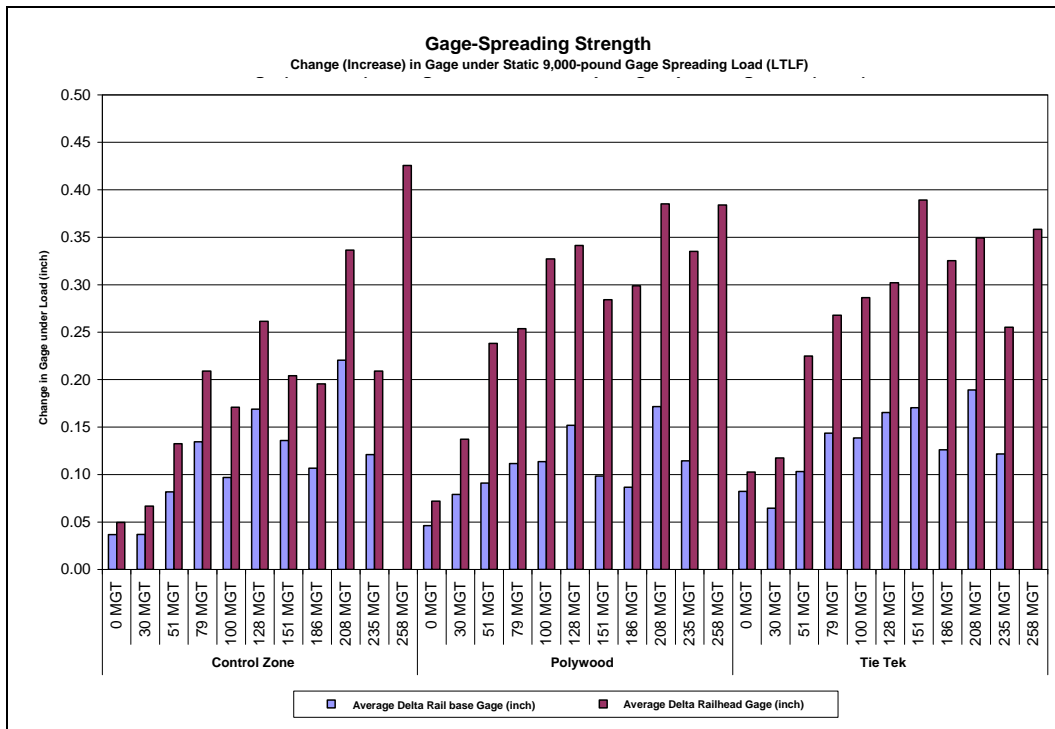


Figure 2. Gage Strength Degradation of Plastic Composite and Wood Ties

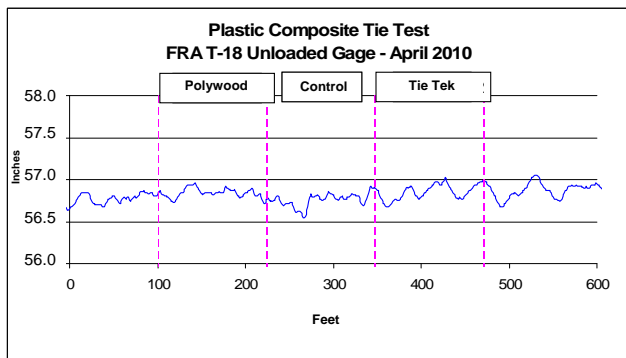


Figure 3. Unloaded Track Gage One Year after Regaging

**Rail Wear**

Railhead profile measurements were taken to determine if the difference in bending stiffness between the plastic composite ties and the wood ties affect rail wear caused by HAL traffic. Four measurements were taken during the life of the test. Figure 4 shows the three cumulative railhead area loss values calculated in each of the three subzones with reference to the first measurement taken. The results indicate that the difference in railhead area loss in the three subzones at the conclusion of the test was less than 0.04 inch<sup>2</sup> (25 millimeters<sup>2</sup>).

**Tie Cracking and Breaking**

At the recommendation of the plastic tie manufacturers during installation of the new ties in November 2004, the cut spikes were driven into the plastic ties without first boring pilot holes. As a result of spiking into the new plastic material, cracking in the rail seat area occurred in just over 4 percent (32 of 750) of the spike locations of Tie Tek plastic ties.

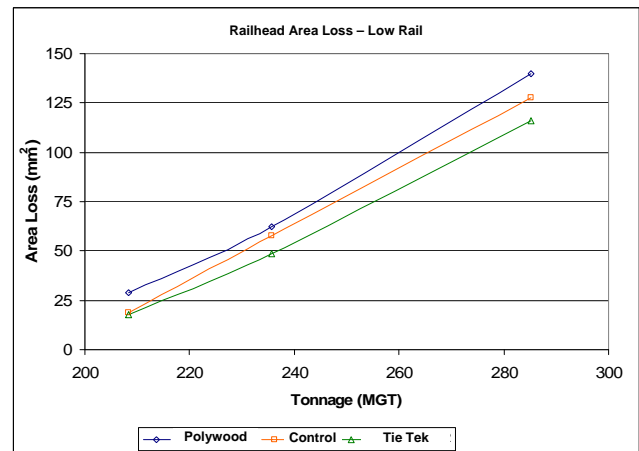


Figure 4. Railhead Area Loss in the Plastic Composite and Wood Tie Test Zones

Polywood ties experienced six cracks, less than 1 percent of the spike locations. None of the cracked ties from either manufacturer broke during the initial installation.<sup>1</sup> As a precautionary measure, however, nine of TieTek cracked ties were replaced with the same type of ties in April 2005 after approximately 30 MGT. The cracks that remained in track did not grow significantly during the remainder of their time in service. The cut spike holding power of the plastic material was not affected by the cracks. In fact, maintenance due to cut spike uplift was not required in either of the plastic tie test zones during the period of performance.

The spikes of the nine plastic replacement ties were driven into pilot holes 3/8-inch in diameter and 3 inches deep. None of the replacement ties cracked during spiking.

An additional benefit of spiking into pilot holes was a significant reduction in the plastic material buildup around the spike holes between the plates and the top of the ties.

In May 2010 when the test was concluded, five of the 75 Tie Tek plastic ties had completely broken in two. In November 2008, one tie (Figure 5) broke at a material void near its center and was replaced. In April 2010, three more Tie Tek ties were found broken during a scheduled NS/TTCI inspection. One month later, as the ties were removed from track, another broken tie was found. These last four ties broke along the transverse, cut spike plane.



Figure 5. Tie Tek Plastic Composite Tie broke at a Material Void near its Center

The four ties that ultimately broke along the spike plane survived until the track was regaged. Three of those ties survived with the cracks that occurred during the initial installation.

Visual inspection indicates the break initiation appears to be located at spikes holes nearest the edge of the tie for the four ties that broke in two along the spike plane. Figure 6 shows visual evidence that the breaks may have occurred as a result of the wedging force of the spikes driven into the synthetic tie plugging material.

The synthetic tie plugging material used during the regaging operation was drilled for pilot holes before the spikes were inserted. A combination of low plastic composite tie material toughness and the nonresilient properties of the plugging material used, however, may have contributed to these ties breaking. None of the Polywood plastic composite ties broke, which suggests different formulations and manufacturing processes may affect the toughness of the material.

### Tie Plate Cutting

Figure 7 shows the condition under a tie plate of one of the Tie Tek plastic composite ties. After more than 280 MGT of HAL traffic, there was no significant deformation or damage. The wood ties also performed well during the test period.



Figure 6. Tie Tek Plastic Composite Tie broke due to Wedging Force of Driving Spike and Very Hard Plugging Material



Figure 7. Tie Tek Plastic Composite Tie with Minimal Damage in Tie Plate Area and Minimal Deformation of the Cut Spike Holes

### Acknowledgements

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