TECHNOLOGY DIGEST

TD-06-015
©JUNE 2006

TIMELY TECHNOLOGY TRANSFER

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In-track Performance of Plastic Composite Ties under Heavy Axle Loads at FAST

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Summary

Wood continues to be the preferred material for use in railway crossties and continues to dominate the market today. In 2005, almost 93 percent of the nearly 14 million new ties installed on Class I railroads were wood.[1] However, during the past decade, manufacturers have been developing ties made from plastic composite materials. These alternative ties are designed to hold gage and maintain surface and alignment, with the added benefit of resisting damage caused by insects and moisture. In 2005 three of the Class I railroads installed over 46,000 plastic ties. Projections for 2006 indicate that the same three Class I railroads will install about 144,000 plastic ties.[2]

Since 1997, Transportation Technology Center, Inc. has been monitoring the in-track performance of plastic composite ties under more than 1,000 million gross tons (MGT) of heavy axle load (HAL) traffic on the High Tonnage Loop at the Facility for Accelerated Service Testing (FAST). Test results and in-track monitoring at FAST indicate that:

- Generally, the plastic composite ties tested at FAST have been able to withstand heavy axle loads in out of face (consecutive-tie) installations and intermixed with wood ties – using cut spike and elastic fastening systems.
- An increasing trend in loaded gage as a function of tonnage was noted. As tonnage continues to accumulate, additional measurements will be taken and a final statistical analysis of degradation will be made.
- The Lewis Bolt & Nut high strength screw spikes used with AirBoss plates in plastic and wood ties (intermixed test zone) required less high spike maintenance (4% high spikes) than the standard No. 5760 screw spikes used with the 16-inch rolled steel plates in plastic and wood ties (13% high spikes) during 540 MGT.
- Tie-plate cutting in the full-size TieTek test zone after 645 MGT was less than 0.05 inch.
- Cracking in the rail seat area of the plastic ties typically developed during initial installation. Cracking occurred significantly more often when screw spikes were used than with cut spikes.
- Screw spike uplift maintenance was not required at cracked locations more than elsewhere.
- None of the ties with cracks installed in open track fractured as a result of HAL traffic. One skewed tie with an existing crack fractured as it was being straightened.
- Cracking in the cut spiked TieTek ties and the Recycle Technologies International ties was not a problem at FAST because pilot holes were used.
- Two of the TieTek plastic frog ties (a 13- and 14-foot tie) that cracked during the initial installation of screw spikes fractured and were removed after about 140 MGT. It is likely that the ties fractured as a result of wheel impacts typically seen over a frog and the two sets of screw spike holes that reduced the cross sectional area of the ties by about 36 percent.
  - There was no major plastic deformation in any of the TieTek frog ties after 238 MGT, and there were no additional fractures.
- Material formulation, manufacturing process, spike pilot hole size, and proximity of the spikes to the edge of the ties all have an effect on the cracking characteristics of plastic ties.

Further laboratory testing is necessary to better understand the cracking and fracture characteristics of plastic composite ties. Issues to consider include: the strength of the rail seat after the cross sectional area of the tie is reduced by cut spike and screw spike holes and the performance under the likely range of temperatures found in revenue service.

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BACKGROUND AND INTRODUCTION

Wood continues to be the preferred material for use in railway crossties and continues to dominate the market today. In 2005, almost 93 percent of the nearly 14 million new ties installed on Class I railroads were wood.[1] However, during the past decade, manufacturers have been developing alternative ties made from plastic composite materials that promise to hold gage, maintain surface and alignment with the added benefit of resisting damage caused by insects and moisture. In 2005, three of the Class I railroads installed over 46,000 plastic ties. Projections for 2006 indicate that the same three Class I railroads will install about 144,000 plastic ties.[2]

Since 1997, TTCI has been monitoring in-track performance of plastic composite ties under more than 1,000 MGT of High Tonnage Loop (HTL) traffic on the HTL at FAST.

PLASTIC COMPOSITE TEST TIES AT FAST

Table 1 lists the plastic composite ties that are currently in service at FAST. Details about the test environment and preliminary results were published in TTCI Technology Digest TD-02-004.[3]

Table 1. Plastic Composite Ties Currently in Service under HAL Traffic on the HTL at FAST

Tie Type (No. Ties)	Installation Date (MGT)	Fastening System	HTL Test Zone Location
USPL smooth (25 ties)	5/97 (1029 MGT)	Elastic & Screw spikes	Section 7, 5-degree 4-inch superelevation
USPL roughened (25 ties)	2/98 (950 MGT)		
TieTek smooth (24 ties)	1/98 (960 MGT)	Elastic & Screw spikes (originally with cut spkes)	
TieTek roughened (100 ties)	8/00 (645 MGT)	Cut spikes	Section 25, 6-degree 5-inch superelevation
TieTek/Wood Intermixed (175 ties – 30% plastic)	4/01 (543 MGT)	Elastic & Screw spikes (Lewis Bolt & Nut)	
Polywood roughened (100 ties)	1/03 (341 MGT)	Cut spikes	Section 3, 5-degree, 4-inch superelevation
TieTek roughened (21 frog ties)	10/03 (233 MGT)	Elastic & Screw spikes (Lewis Bolt & Nut)	Turnout No. 405, under No. 10 RBM frog
RTI (100 ties)	5/04 (182 MGT)	Cut spikes	Section 25, 6-degree, 5-inch superelevation
PRT, LP (100 ties)	11/05 (15MGT)		

CRACKS IN PLASTIC COMPOSITE TIES AT FAST

TTCI has been monitoring cracks in plastic ties since the prototype test zone was installed at FAST in 1997. Cracks typically developed as the plates were fastened to the ties using screw spikes.

US Plastic Lumber Limited-Size Test Zone

The first of the 50 US Plastic Lumber (USPL) ties was installed in May 1997 using Pandrol 16-inch rolled-steel tie plates and e-clips with 15/16 inch diameter and No. 5760 screw spikes in 5/8-inch pilot holes. Numerous cracks developed during tie plate installation. These cracks originated at the screw spike holes. Although some crack growth occurred during more than 1,000 MGT of service, none of the ties has been removed due to fracture or screw spike uplift.

TieTek Limited-Size Test Zone

The 24 TieTek ties that were installed in January 1998 with 14-inch tie plates and cut spikes in 3/8-inch pilot holes have been in service more than 960 MGT. There was no cracking during the initial cut spike installation. The screw spike system currently in place has not caused cracks.

TieTek Full-Size Test Zone

The 100-tie test zone was installed in August 2000 using 14-inch tie plates and standard 5/8-inch x 5/8-inch square cut spikes in 3/8-inch pilot holes. The cut spikes, which were inserted by impact, did not cause cracks and none have developed while in service during 645 MGT. After 161 MGT, high spikes on the gage side of the high rail were knocked down in a 19-tie section where mechanical joints caused localized track pumping under traffic. No additional high spike maintenance was required until the test zone had been in service over 635 MGT. At that point, the gage spikes on the high side of a 65-tie section were knocked down. The ties provided good holding power for the cut spikes after they were reinserted into existing holes without plugging over a 20-tie section of track.

TieTek Plastic Tie/Wood Tie Intermixed Test Zone

The general performance of the plastic tie/wood tie test zone indicates that plastic ties can be intermixed effectively with wood ties in a HAL environment. The test zone has been in service since April 2001 and more than 543 MGT. The two fastening systems used in this test zone are the Pandrol 16-inch rolled-steel tie plate and e-clips with No. 5760 screw spikes and the AirBoss 16-inch cast tie plates and rail clips with Lewis Bolt & Nut (LB&N) high strength screw spikes.

Cracks developed in five of the five ties drilled with 1/2-inch pilot holes. One tie cracked severely and was not installed, one tie fractured while straightening skewed ties, and three ties remain in-track. Seventeen of 36 ties drilled with 5/8-inch pilot holes cracked and although none fractured, they were not installed in-track. Except for three ties with 1/2-inch pilot holes, all remaining ties in the test zone were drilled with 11/16-inch pilot holes. There was significantly less cracking with 11/16-inch pilot holes, where 12 of 448 (<3%) screw spikes caused cracks, than with 1/2- or 5/8-inch holes.

Tracking the maintenance requirements of different ties and fastening systems is a major part of the long-term in-track performance evaluation at FAST. TTCI documents all the maintenance that is performed in the test zones including the work done to correct screw spike uplift. The maintenance record shown in Table 2 indicates that in the plastic ties and the wood ties with the LB&N high strength screw spikes in the AirBoss system required less screw spike uplift maintenance than the No. 5760 screw spikes in the 16-inch rolled-steel plate system. The pitch of the screw spike threads, the core diameter, and the location of the spikes relative to the centerline of the rail may have an effect on uplift.

Table 2. Maintenance Performed during 540 MGT in the Plastic-Tie/Wood-Tie Intermixed Test Zone when the Screw Spikes Uplifted over 2 Inches

	LB&N High Strength Screw Spikes in AirBoss Plates		Standard No. 5760 Screw Spikes in 16-inch Rolled-Steel Plates	
	Plastic Ties (36 ties – 288 ss)	Wood Ties (83 ties – 664 ss)	Plastic Ties (20 ties – 160 ss)	Wood Ties (35 ties – 280 ss)
Screw Spike Uplift >2-inches	14 (5%)	24 (4%)	34 (21%)	31 (11%)

Polywood Full-Size Test Zone

The Polywood plastic composite tie test zone has been in service over 340 MGT. The ties were installed in January 2003 in the 5-degree, 4-inch superelevation curve of HTL Section 3 under a proprietary agreement with the manufacturer. The 100-tie zone is fitted with 14-inch tie plates and cut spikes in 1/2-inch diameter pilot holes. After the proprietary test period of 100 MGT, Polywood donated the ties to TTCI for further observation. After 241 MGT, one hairline crack was found in the test zone. No additional cracks have been found, and no high spike maintenance has been required. The ties continue to perform well under HAL traffic.

TieTek Frog Tie Test

In October 2003, 21 ties ranging in length from 12 to 16 feet were installed under a No. 10 spring frog at Switch No. 405. The ties, which have been in service over 233 MGT, were fastened with 15/16-inch LB&N high strength screw spikes in dual-diameter pilot holes. Pilot holes of 11/16-inch diameter were made for the threaded portion of the screw spike and 7/8 inch diameter for the neck. Several cracks developed during installation where the frog's platework placed the screw spikes near the edge of the ties.

After about 100 MGT, the spring frog was replaced with a railbound manganese (RBM) frog. To accommodate the RBM frog with its different plate work and spike hole pattern, new 11/16-inch pilot holes were made, the old holes were wood plugged, and new cracks developed in the new holes. The cracks did not appear to have affected the performance of the ties until the test zone had been in service over 140 MGT. As the first RBM frog was removed to install a new one at 140 MGT, two fractured ties were discovered; one 13-foot tie was directly under the frog point and one 14-foot tie was two ties ahead of the point. Figure 1 shows that the fractures occurred along the transverse plane where the two sets of screw spike holes reduced the cross sectional area of the tie by about 36 percent. The two plugged holes are from the first frog, and the two open holes are from the second frog.

Figure 1. Frog Tie Fractured along the Transverse Plane where Two Sets of Screw Spike Holes Significantly Reduced the Cross Sectional Area of the Tie

Measurements of the dynamic vertical load environment over the frog were taken with TTCI's instrumented wheelset. Data indicates that 95th percentile vertical loads were about 45 kips. The maximum load measured over the frog was 66.2 kips, almost 1.7 times static wheel load (39 kips). The two fractured ties were replaced with two spare TieTek ties. There have been no additional fractures during 93 MGT.

Top of rail and top of tie elevation measurements were taken periodically over one tie of each length installed (12 to 16 feet) to monitor deformation. After 238 MGT, there was no major deformation in any of the ties measured.

Recycle Technologies International Full-Size Test Zone

The 100-tie RTI test zone has accumulated more than 180 MGT since it was installed in May 2004. Seventeen ties from the original shipment were rejected due to swelled surfaces that did not allow flat seating of the tie plates. One tie was rejected due to 1.5-inch bowing at the center. RTI replaced the rejected ties and the full-test zone was installed. Although there has been some minor cut spike uplift, no maintenance has been required. Cracking did not occur when the cut spikes were driven into 1/2-inch pilot holes, and none has developed while in service.

TRACK GAGE STRENGTH

In-track performance evaluations of ties and fasteners at FAST include periodic measurements of loaded track gage using TTCI's Track Loading Vehicle (TLV). The TLV applies a 0.55 L/V load (18 kip lateral / 33 kip vertical) to the track and measures the resulting gage as it traverses the test zones at about 12 mph. Figure 2 shows a comparison of the loaded gage in three test zones: (1) a typical hardwood (gum) test zone, (2) the 100-tie TieTek test zone with cut spikes, and (3) the TieTek/wood-tie intermixed test zone with AirBoss tie plates, rail clips, and LB&N screw spikes. The graph indicates an increasing trend in loaded gage as a function of tonnage. As tonnage continues to accumulate, additional measurements will be taken and a final statistical analysis of degradation will be made. The lower overall loaded gage measured in the TieTek test zone is not necessarily an indication of stronger track, but rather a case where the track was gaged tighter than the others when installed. Delta gage (the difference between unloaded and loaded gage) is another measure of track strength. TLV delta gage data indicates that the plastic ties are performing similarly to the gum ties.

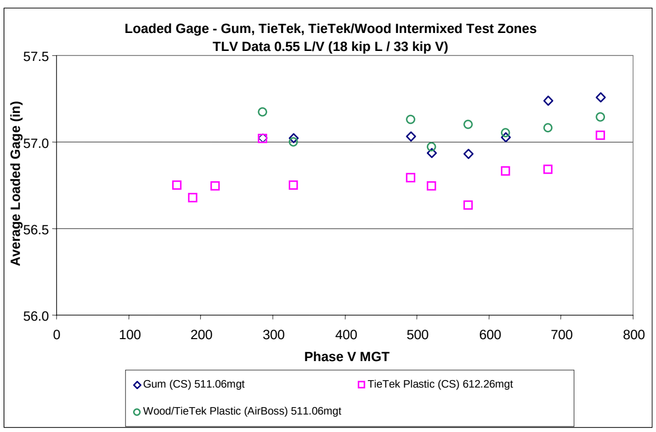

Figure 2. A Comparison of Loaded Gage in a Gum Wood-Tie Test Zone, a 100-tie TieTek Zone, and an Intermixed Test Zone of TieTek Plastic Ties and Wood Ties

TIE-PLATE CUTTING AND RAIL SEAT AREA COMPRESSION

Tie-plate cutting and rail seat area compression were measured using a 24-inch straight edge. After 645 MGT, the tie-plate cutting and compression measured in the full-size test zone that has been in service longest (TieTek 645 MGT) was minimal, less than 0.05 inch under the field-side of the high rail.

TIE-CENTER DEFLECTION UNDER STATIC LOAD

The tie-center deflection of plastic ties from four manufacturers is being monitored under static load to evaluate long-term deformation. The ties are simply supported using 9-inch-wide blocks to create a 60-inch span at the center. The center of each span is loaded with a 350-pound static load. The deflection at the center of the 60-inch spans is measured periodically and compared over time.

The TieTek tie was set up in October 2002 with 275 pounds and the Polywood, RTI, and USPL ties were added to the test in August 2004 with the same load. The static load was increased to 350 pounds on the four ties in July 2005. The maximum tie-center deflection measured to date in each tie is as follows: USPL 0.07 inch; Polywood 0.17 inch, TieTek 0.24 inch, and the RTI 0.40 inch. Resistance to tie-center deflection is a favorable tie characteristic.

STEEL-REINFORCED PLASTIC COMPOSITE TIES

In November 2005, a full-size, 100-tie test zone of plastic composite ties from Performance Rail Tie, LP (PRT) was installed in the 6-degree curve of the HTL. The PRT ties have a steel-reinforced spine insert designed for increased stiffness and side cavities and bottom ribs designed for increased lateral resistance.

The ties were installed with standard AREMA 14-inch tie plates and cut spikes in 1/2-inch diameter pilot holes of various depths. Nineteen cracks developed and eight cross section fractures in the rail seat area occurred during the initial installation as the cut spikes were inserted. PRT has modified the manufacturing process to address the cracking/fracturing issue.

ACKNOWLEDGEMENTS

TTCI thanks the manufacturers and suppliers who donated material for this test: TieTek, Inc., US Plastic Lumber, Polywood, Inc., Recycle Technologies, Inc., and Performance Rail Tie, LP for the plastic composite ties; AirBoss Railway Products, Inc. and Pandrol USA for the tie plates; and Lewis Bolt & Nut Co. for the high-strength screw spikes.

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