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Contact **Rafael Jimenez, (719) 584-0691** with questions regarding this *Technology Digest*. E-mail: Rafael_jimenez@ttci.aar.com.

An Evaluation of the Effect of Temperature on the Vertical Stiffness and the Gage-Spreading Strength of Plastic Composite Tie Track

by **Rafael Jimenez and Charity Sasaoka**

Summary

Since 1997, plastic composite ties have been monitored in service under heavy axle load (HAL) conditions for over 770 million gross ton (MGT) on the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST), Transportation Technology Center.

Tests have been conducted to evaluate the effect of temperature on the vertical track stiffness and the gage-spreading strength of the plastic composite tie test zones located in 5- and 6-degree curves. Tests were also performed at Transportation Technology Center, Inc.'s (TTCI) Component Test Laboratory to quantify the linear thermal expansion that can be expected in a tie made of plastic composite material.

The results indicate that:

- There was no major difference in vertical track stiffness between the plastic composite tie track and the oak-tie track.
 - In static tests, the vertical stiffness of the plastic composite tie track and the oak-tie track was within a 270-lb/in/in range between 3,160 lbs/in/in and 3,430 lbs/in/in during an 88-degree change in tie-center temperature.
 - The dynamic measurements taken with Transportation Technology Center, Inc.'s (TTCI) Track Loading Vehicle (TLV) show similar results.
- In the semi-arid climate at FAST and the strong track support conditions characterized by the silty sand subgrade and clean ballast, there was no significant change in vertical track stiffness that can be attributed to the change in plastic composite tie temperature within the range evaluated.
- There was no evidence of major temperature effect on the gage-spreading strength of the plastic composite tie test zone in:

Lateral Track Loading Fixture (LTLF) Tests:

- A steady state of gage-spreading strength appears to have been reached by 50 MGT of HAL traffic.
- After an initial delta gage of 0.13 inch, before traffic was allowed over the test zone, the gage strength in the test zone has remained relatively constant within a 0.09-inch delta gage range, between 0.21 and 0.30 inch.
- All measurements were taken when the rail temperature was between 14°F and 80°F.

TLV Tests:

- The maximum delta gage measured in the test zone under in-motion 0.5 L/V loading (18-kip lateral/33-kip vertical) was 0.22 inch, during ambient temperatures that ranged between 24°F and 73°F.
- The material tested can be expected to experience a 0.24-inch change in length in 60 inches for a 100°F change in material temperature compared to 0.016-inch in an oak tie.¹
 - The average change in unloaded gage measured in the plastic composite tie test zone over an 84°F change in reference rail temperature was about 0.21 inch.

Suggested Distribution:

- Maintenance-of-Way
- Track Maintenance
- Planning & Analysis



INTRODUCTION AND BACKGROUND

Vertical track stiffness and gage-spreading strength tests were conducted as part of TTCI’s continued testing and monitoring of the long-term performance of plastic composite ties that began in May 1997. The Federal Railroad Administration (FRA) funded the track stiffness tests. All other tests were performed under the FRA and Association of American Railroad jointly funded Heavy Axle Load (HAL) Program.

TieTek, Inc. and USPL, LTD donated the plastic composite ties tested. The in-track tests were performed on the High Tonnage Loop (HTL) at FRA’s Facility for Accelerated Service Testing (FAST). Table 1 shows the testing environment on the HTL.

TESTING

Gage-Spreading Strength

Lateral Track Loading Fixture (LTLF)

The gage-spreading strength of the plastic composite tie test zone in the 6-degree curve has been monitored using a LTLF since it was installed in August 2000. The portable, hydraulic unit applies a lateral (rail to rail) static gage-spreading force at specific sites. Measurements of the resulting high- and low-railhead displacements are taken at five locations throughout the test zone. Figure 1 is a graph of delta gage — the total high- and low-railhead displacement at each location — measured at MGT intervals. The average rail temperature during each measurement cycle is also shown.

Figure 1 shows that the delta gage of the newly installed plastic composite tie track, before any traffic, was about 0.13 inch. A steady state of gage strength appears to have been reached by the second measurement cycle after 50 MGT of traffic. During the

six subsequent measurements, where the rail temperature varied about 66°F between 14°F and 80°F, delta gage remained within a 0.09-inch range, between 0.21 inch and 0.30 inch.

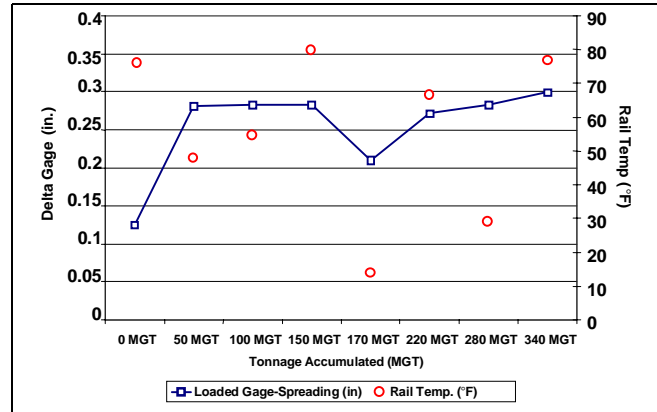


Figure 1. Static Gage-Spreading Strength of the Plastic Composite Tie Test Zone in the 6-degree Curve
(Delta gage and rail temperature — LTLF Measurements)

Track Loading Vehicle (TLV)

In addition to its capability for measuring vertical track deflection in stiffness testing, the TLV also performs in-motion gage-spreading strength tests, where the track is continuously loaded at a 0.5 L/V ratio (18 kip lateral / 33 kip vertical). Measurements were taken in the plastic tie test zone of the 6-degree curve during ambient temperatures that ranged from 24°F to 73°F. Delta gage—the difference between unloaded gage and the gage under the 0.5 L/V load—has varied 0.22 inch, between 0.29 inch and 0.51 inch. The increase in track gage that was measured during warm weather led to a laboratory evaluation of the linear thermal expansion of the plastic composite material.

Table 1. Environment at Time of Testing

Location	HTL at FAST
Climate	Semi-arid
Track Geometry	6-degree, 5-inch superelevation curve and 5-degree, 4-inch superelevation curve. Track is maintained to FRA Class 4 Track Safety Standards.
Configuration	100 TieTek Ties in the 6-degree curve (about 163 track-ft.) 50 USPL Ties in the 5-degree curve (about 82 track-ft.) 19.5-inch on center tie spacing
Fasteners	Cut spikes in the 6-degree curve Pandrol® e-Clips and Screw spikes in the 5-degree curve
Ballast Section	Existing ballast; Nominal 18-inch depth with 15-inch shoulders
Subgrade	Silty Sand
Rail Section	136, and 141 lb-per-yard welded rail
HAL Train	Sixty to Eighty 315,000 lb. (39-ton axle load) cars.
Operating Speed	40 MPH
Truck Suspension	Standard Suspension Trucks
Accumulation of Tonnage	About 110 MGT per year

LINEAR THERMAL EXPANSION

TTCI performed laboratory tests to determine the coefficient of thermal expansion of the TieTek plastic composite tie material. Table 2 shows that for the thermal coefficient calculated (3.93×10^{-5}), a 0.24-inch change in length can be expected in a 60-inch span for a 100°F change in temperature, as compared to 0.016 inch in reference oak ties under the same conditions. Sixty inches is the approximate centerline distance between rails set at standard gage.

Table 2. Coefficient of Linear Expansion for TieTek Plastic Composite Material and Oakwood and the Expected Change in Length in a 60-inch Span

Tie Material	Coefficient of Linear Expansion	Δ Temperature Degrees Fahrenheit	Sample Length (in.)	Δ Length (in.)
TieTek Plastic Composite Material*	3.93×10^{-5}	100	60	0.24
Oak ¹	0.27×10^{-5}			0.016

*Tested at TTCI

Since installed, the unloaded track gage of the plastic composite tie test zone in the 6-degree curve has been measured periodically using a portable gage-measuring device. As a reference, the rail temperature was recorded during each measurement cycle. The lowest rail temperature recorded during a cold weather measurement cycle was 14°F; the highest rail temperature recorded was 98°F during a warm weather cycle. The change in gage measured for the 84°F change, in reference rail temperature, was about 0.21 inch.

VERTICAL TRACK MODULUS (STIFFNESS)

Track modulus tests, using vertical deflection under load, were performed to evaluate the effect of temperature on the vertical stiffness of plastic composite tie track and to compare to the stiffness of oak-tie track. The plastic composite tie test zone and the oak-tie test zone, each

consisting of 100 ties (163 track-ft), are adjacent in the 6-degree, 5-inch superelevation curve of the HTL.

Static and dynamic tests were performed in warm- and cold-weather during the late summer and winter of 2002. To monitor tie temperature during testing, one plastic tie at mid-test zone was instrumented with thermocouples. One thermocouple was installed inside the center of the tie at the neutral axis and another thermocouple was attached to the top surface center of the same tie.

It is important to note that the semi-arid climate, the silty sand subgrade, and the clean ballast, in which these tests were performed, all contribute to the strong track support conditions found at FAST.

Static Measurements

The static tests in the 6-degree curve were conducted using TTCI's Rail Force Calibration Car No. 605. Vertical track deflection (both rails) was measured every five ties (19 measurements) throughout the test and control zones under 40-kip wheel loads. Ten measurements were taken in the 5-degree curve.

Table 3 lists the average calculated vertical track modulus (low and high rails) under the warm- and cold-weather test conditions.² Also given is the tonnage accumulated over the test zones at the time of testing and the average temperature in the center and on top of one plastic composite tie during testing.

The results show that for an 88°F average reduction in the center-of-tie temperature (the difference between the labeled Warm-Weather and Cold-Weather measurement cycles), which occurred during a 57°F reduction in ambient temperature, there was an average increase in vertical track stiffness of about 7.5 percent in the plastic composite tie track. The average increase in stiffness in the oak-tie track during the same change in ambient temperature was about 2.5 percent.

Table 3. Vertical Track Modulus (Static Measurements) of Plastic Composite and Oak-Tie Track in the 6-Degree Curve

Test (Avg. Ambient Temp °F)	Track (MGT)	Avg. Top of Plastic Tie Temp (°F)	Avg. Center of Plastic Tie Temp (°F)	Avg. Track Modulus (lb/in/in)
Warm Weather (91°)	Plastic Composite Tie Track (232)	130°	121°	3,190
	Oak-Tie Track (783)	NA	NA	3,160
Cold Weather (34°)	Plastic Composite Tie Track (280)	58°	33°	3,430
	Oak-Tie Track (830)	NA	NA	3,240

The track stiffness of the plastic composite tie track and the oak-tie track during the warm- and the cold-weather measurement cycles was within a 270-lb/in/in range between 3,160 lb/in/in and 3,430 lb/in/in in the 6-degree curve. The stiffness values measured in the plastic composite ties of the 5-degree curve, some of which had been in service over 650 MGT, were higher, about 4,460 lb/in/in during the warm-weather cycle (111°F average center of tie temp) and about 5,130 lb/in/in during cold-weather (27°F average center of tie temp).

Dynamic Measurements

Dynamic vertical deflection of the low rail was measured using the TLV. The measurements were taken at 10 mph as the TLV applied a 40-kip vertical wheel load. The entire 6-degree curve was measured during each of the measurement cycles. This allowed for a relative comparison of the stiffness in plastic composite tie track with numerous wood-tie track test zones of different species also located in the curve.

The average ambient temperature during the warm-weather measurement cycle was about 81°F. During the cold-weather cycle, it was about 24°F. Concurrently, the center of plastic tie temperature was about 111°F during the warm-weather measurement cycle and about 42°F during the cold-weather cycle, a 71°F change in temperature.

Generally, for the temperature range during which the dynamic measurements were taken, the low-rail stiffness throughout the curve, including the plastic composite tie test zone, was between 2,600 lb/in/in and 3,700 lb/in/in. The results indicate that there was no significant difference between the cold-

and the warm-weather measurements taken in the plastic composite tie test zone and the same measurements taken in the rest of the curve.

Tie-Center Deformation

A preliminary evaluation of tie-center deformation has been in place since April 2002. Two full-length TieTek plastic composite ties were simply supported using 9-inch-wide supports and a 60-inch span on a flat concrete surface. On October 29, 2002, a static load of about 270 pounds of rail sections was placed over 18 inches in the center of one tie. During the time that the ties have been monitored, the ambient temperature has varied between -10°F (2/7/03) and 109°F (7/13/03). To date there has been no major permanent deformation in either the loaded or the unloaded tie.

FUTURE WORK

TTCI will continue to monitor the plastic composite test ties at FAST to determine their long-term performance characteristics under heavy axle load traffic.

Acknowledgements

Our appreciation to TieTek, Inc. and USPL LTD for donating the plastic composite test ties.

References

1. American Institute of Steel Construction, *Manual of Steel Construction*, Ninth Edition, 1989.
2. U.S. Department of Transportation, Federal Railroad Administration, Office of Research and Development, "Vertical Track Modulus in Plastic Composite Tie Test Zones at FAST," DOT/FRA/ORD-03/13, January 24, 2003.

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