TECHNOLOGY DIGEST

Timely Technology Transfer — 00-015

Final Results of Steel-Tie Testing at FAST

by Rafael Jimenez, David Davis, and Joseph LoPresti

Summary

In-track performance testing by Transportation Technology Center, Inc. indicates that under test conditions at the Facility for Accelerated Service Testing (FAST) at the Federal Railroad Administration's Transportation Technology Center, steel-tie and typical wood-tie tracks do not perform the same under heavy axle loads.

The steel ties required frequent maintenance. They demonstrated poor dynamic performance under load that resulted in rapid ballast degradation and occasional slow orders. The major part of the test was concluded when most ties had accumulated about 170 million gross tons (MGT) of 39-ton operations; however, 50 ties accumulated a total of 360 MGT. The steel-tie test provided both positive and negative findings.

On the negative side:

- Track surface maintenance throughout the test zone was required about every 7 MGT. Comparison wood-tie track at FAST required surfacing at about 150 MGT intervals.
- Curvature realignment was performed seven times during 170 MGT in the steel-tie test zone. No realignment was required in the wood-tie comparison zone during the entire period of performance.
- Ballast migration from the shoulders and tie cribs on the high side of the curve to the low rail required regular maintenance.
- There was significantly more ballast degradation in the steel-tie test zone than in the wood-tie transition zone.
- Under the dynamic load of normal heavy axle load (HAL) operations at FAST, track pumping (vertical track deflections) caused cars in the steel-tie zone to rock more than cars in adjacent wood-tie zones. This track pumping caused the surface maintenance that was required, the degradation of ballast, and may have contributed to the curvature degradation that occurred during the test.

On the positive side:

- The single-tie lateral resistance of the steel ties tested was greater than that of wood ties under both newly installed and after-consolidated conditions.
- Although wood-tie track resistance to track panel shift is similar to that of steel-tie track in after-consolidated condition, steel-tie track provided greater resistance than wood-tie track when newly installed.
- The steel ties provided better restraint to gage-widening than wood ties using either cut spikes or elastic fasteners.
- After 360 MGT there was no significant wear on the steel-tie rail seats, the rail-seat pads, the rail clip insulators, or the hook-in shoulders.
- Transition zones, consisting of 20 wood ties with elastic fasteners, performed well between the steel-tie test section and the adjacent wood-tie section with cut spike fastener track.

Suggested Distribution:

☐ Maintenance of Way
☐ Planning & Analysis
☐ Track Maintenance
☐ Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads
August 2000

BACKGROUND

Though hardwood and concrete ties perform well under heavy axle load conditions (1,000 MGT at FAST), suppliers continue to develop ties made of alternative materials. Some of the intended benefits of these ties include economic, performance, environmental, or operational benefits, such as improved clearance. The objective of the recently concluded test at the Facility for Accelerated Service Testing (FAST) was to quantify the performance of steel ties in curved track under 39-ton heavy axle load (HAL) traffic operating at 40 mph.

The steel-tie test consisted of two parts. This report documents Part 2 testing. Part 2 of the test was conducted on a section of track 200 ties long, with 100 ties from two manufacturers. One hundred thirty-six steel ties were located in the body of the Section 25, 6-degree curve. The remaining 64 ties stretched into curve-spiral Section 26. Fifty ties from Part 1 were used in Part 2, and had accumulated 360 million gross tons (MGT) by the end of the test. The other 150 ties were new at the start of Part 2, and accumulated 170 MGT.

Part 1 of the test indicated that transitions from wood ties with cut spikes to steel ties with elastic fasteners required more surfacing than the rest of the test zone. To reduce this effect, a 20-tie transition zone was established at each end of the Part 2 steel-tie zone. The transitions consisted of 20 solid-sawn wood ties with the same elastic fastener type as the steel ties to which they were adjacent. The transition at the Tie & Track System end of the test zone was fastened with Safelok® rail clips and the 20-tie transition at the North American Railway Steel Tie Company end of the test zone was fastened with Pandrol® e-clips.

A zone of 100 wood ties adjacent to the steel-tie/transition test zone was used to make general performance comparisons. At the beginning of testing, the wood-tie comparison zone was surfaced out of face and lined to create a newly tamped condition to compare with the newly installed condition of the steel ties.

TESTS AND RESULTS

Loaded Vertical Track Deflection Test

Vertical deflection under a static load was measured using a 40-ton axle load car. An automatic level was used to measure top of rail elevations every three ties over the unloaded test zone, and again under the loaded car at the same locations. Exhibit 1 indicates that most deflections measured in the wood-tie comparison zone were under 0.4 inch. The uniformity of deflections are indicative of the relatively smooth "ride" over the wood-tie track. Although most of the low-rail deflections measured in the steel-tie zone were also less than 0.4 inch, many high rail deflections were more than 0.5 inch, and there was much more scatter. The measured deflections correspond with the pumping and car rocking observed during HAL train operations.

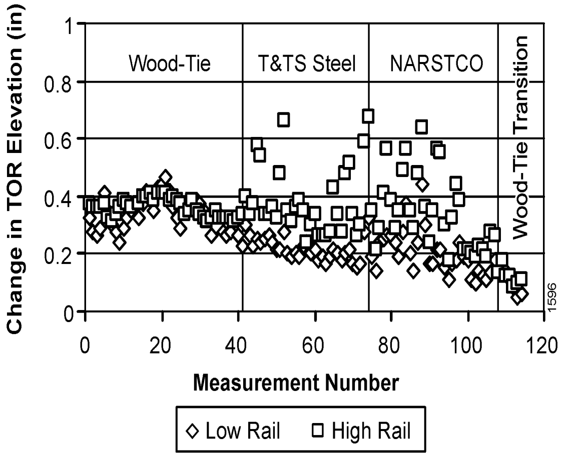

Exhibit 1. Vertical Track Deflections under Static 40-ton Axle Load in the Steel-Tie Test Zone and in the Adjacent Wood-Tie Comparison Zone

Gage-Widening Restraint

Track strength and geometry on the High Tonnage Loop are periodically measured by the Federal Railroad Administration's Gage Restraint Measurement System (GRMS) system. For the gage-widening strength test, the GRMS "split-axle" applies controlled, gage-widening loads (14-kip lateral/20-kip vertical) to the rails while in motion. The test results are used to calculate gage-widening ratio (GWR). The GWR index measures the change in gage caused by an applied load, and normalizes the amount of deflection to a constant load. The steel ties provide more gage-widening restraint than wood ties with either cut spikes or elastic fasteners. Exhibit 2 shows the GWR in the wood-tie and steel-tie test zones in Section 25/26.

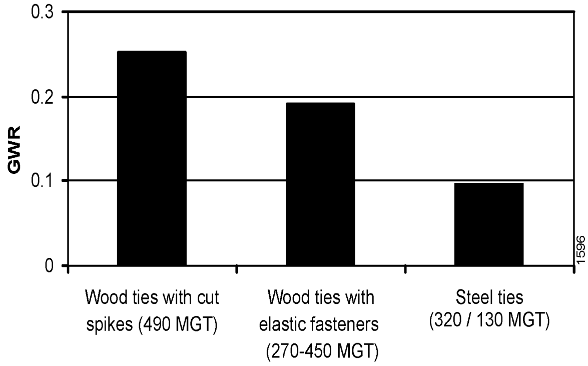

Exhibit 2. Gage-Widening Ratio from GRMS Data

Gage-widening ratio (GWR) is calculated as follows:

$$GWR = \frac{G_L - G_U}{L_A} \text{ (16,000 lb)}$$

Where: G_L = Loaded Track Gage
G_U = Unloaded Track Gage
L_A = Applied Lateral Load

Lateral Track Strength

Single tie push tests (STPTs) were made on four ties in each zone to determine the average single-tie lateral resistance of each tie type. This test is conducted using the STPT fixture, which consists of a hydraulic cylinder mounted on the top surface of the tie. As the cylinder reacts on the low rail and pushes the tie to the high side of the curve, the resistance and tie displacement are plotted. The peak resistance within the first inch of tie displacement is used to define the single tie lateral resistance. Exhibit 3 compares the single tie lateral resistance of wood ties and each of the two steel-tie types tested. The graph shows that the single-tie lateral resistance of the steel ties tested was greater than that of wood ties under both newly installed and after-consolidated conditions.

Dynamic track-panel shift measurements taken with TTCI's Track Loading Vehicle (TLV) also showed that the steel ties provided more resistance to lateral movement than wood ties when newly installed. TLV measurements indicated that the after-consolidated resistances were similar.

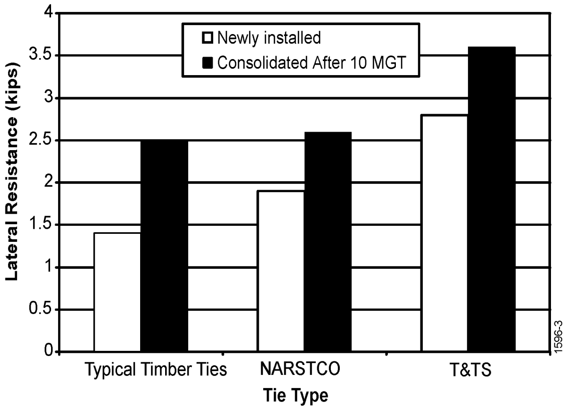

Exhibit 3. Results of the Single-tie Push Tests

BALLAST-SIZE DISTRIBUTION

When the ties were removed at the end of the test, ballast samples were taken under the rail seat area at two locations of the steel-tie zone and one location in the wood-tie transition zone. The ballast placed during tie installation consisted of granite with an American Railway Engineering and Maintenance of Way Association (AREMA) No. 4A size distribution (hatch area in Exhibit 4 shows distribution range). New ballast added during surfacing maintenance was of the same material and gradation. The ballast-size distribution plotted in Exhibit 4 shows significantly more ballast degradation in the steel-tie test zone compared to the wood-tie zone. Ballast degradation in the steel-tie test zone was due to track-pumping action under the passing HAL train and the numerous tamping cycles.

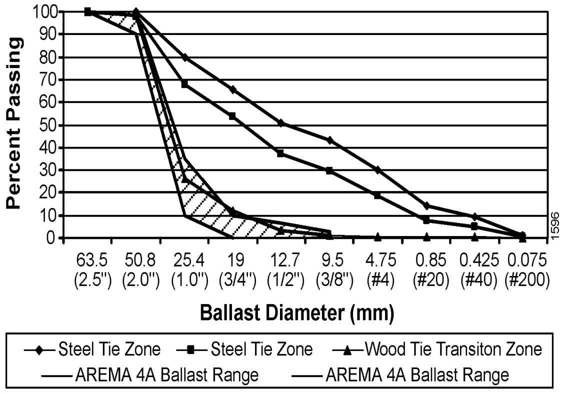

Exhibit 4. Comparison of Ballast-Size Distribution

OBSERVATIONS

Track Maintenance

Surface

Track surfacing to correct track pumping under the HAL train was the single greatest maintenance requirement in the steel-tie test zone. Tamping was necessary about every 7 MGT. Although track pumping occurred throughout the test zone, track near rail discontinuities such as mechanical joints and field welds required much of the maintenance. The transition zones, wood ties with the same elastic fastener type as the steel ties to which they were adjacent, reduced the need for maintenance at the transitions from wood to steel ties.

The method of tamping affected the frequency of track surface maintenance. At the beginning of Part 2 testing, the 100-tie zone of one manufacturer was tamped in the center in addition to under the rail seats. The other 100-tie zone was tamped under the rail seats only (both practices were according to the recommendations of the manufacturers). After about 20 MGT, a sharp increase in the number of tamping cycles in the zone tamped under the rail seats only prompted a change in tamping policy. The rail seats and the centers were tamped. Exhibit 5 shows that after center tamping began, surfacing requirements for both tie types was similar. The wood tie comparison zone did not require surface maintenance during the same peirod.

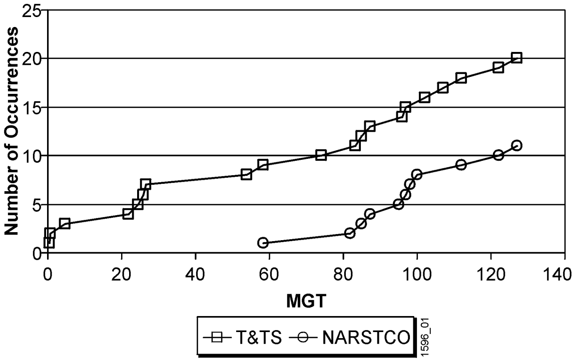

Exhibit 5. Track Surface Maintenance on the 200-Tie Test Zone

Alignment

During the 170 MGT test, realignment was needed seven times. The entire test zone was realigned six times using a production tamper. Additionally, a 60-tie (110 track feet) section was realigned after it kicked out under the train during daytime operations with 110-degree rail temperature. The single tie push results indicate that steel-tie track should provide greater resistance to lateral loads, and therefore, better curvature restraint. But, the STPT is a static test, and the dynamic environment under the 40-mph HAL train is more severe. The pumping that occurred in the steel-tie track may have produced a "walking" effect that caused the curve to move inward, that is, to flatten. No realignment was required in the wood-tie comparison zone.

Ballast Migration

Vertical track pumping action throughout the steel-tie test zone caused the ballast to migrate from the high side of the curve to the low rail, leaving the shoulders and tie cribs shy of ballast. A ballast regulator was used to transfer ballast back to the high side of the curve. Exhibit 6 shows ballast migration and degradation.

Exhibit 6. Ballast Degradation and Displacement from the High-Side Cribs — Typical Condition Caused by Track Pumping

Tie Condition

Visual inspection of the ties in track for 360 MGT revealed that although some light compression marks were visible on the rail-seat pads, there was no significant wear. And no wear was evident on the rail seat area of the ties, the hook-in shoulders or their mounting holes, or the rail clip insulators.

CONCLUSIONS

Under conditions at FAST, the amount of maintenance required to stay within TTCI track standards was too high. Under different operating conditions, in different applications, or at other locations, the performance of steel ties may differ.

ACKNOWLEDGMENT

The authors acknowledge the test-design guidance provided by Technical Advisory Group members: David Connell, UPRR; Russ Dasko, CP, and David Kelly, IC. We also thank North American Railway Steel Tie Corporation and Tie & Track Systems for the donation of the steel ties tested.

Note: Please contact Rafael Jimenez at (719) 584-0691 with questions or comments about this document.
E-mail: rafael_jimenez@ttci.aar.com
Web site: www.ttci.aar.com

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. Box 79780, BALTIMORE, MD, 21279-0780.