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Improving Performance of Crossties and Fasteners

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Summary

In a three-phase program, Transportation Technology Center, Inc. is comparing the performance of various crossties and fastener designs under heavy axle loads to identify problems with current design and materials (Phase 1), to quantify the load environment (Phase 2), and to recommend design guidelines (Phase 3).

Various crosstie and fastener combinations have been installed in track in the High Tonnage Loop at the Facility for Accelerated Service Testing (FAST).

Observations and findings of Phase 1 to date include:

- Composite Tie Durability
  - TieTek and RTI plastic composite ties have accumulated 1,400 and 1,000 million gross tons (MGT), respectively. No performance related failures have been observed during this time.
- Track Gage Widening Resistance
  - Track gage strength of wood ties with elastic fasteners is comparable to concrete ties at FAST.
  - Softwood ties (red pine) with cut spikes showed the highest track gage widening during 255 MGT of service life, followed by hardwood ties with cut spikes.
- Tie Plate Cutting
  - TieTek plastic ties had 4 times higher tonnage; however, the average tie plate cutting depth was one-third of the wood ties, indicating that composite materials may have better resistance to tie plate cutting.
  - Within the wood tie zone, tie plate cutting on softwood ties was twice that of hardwood ties.
- Tie Plate Performance
  - 26 percent of the AREMA standard 14-inch tie plates broke on the TieTek composite ties during 1,400 MGT. No significant tie plate failures were observed in the same type of tie plates on wood ties with similar tonnage. Lower plastic tie bending stiffness is the likely reason for tie plate breakages.
- Fastener System Performance
  - After 255 MGT of heavy axle load traffic, no measureable performance difference was recorded among elastic fastening systems of various vendors.

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INTRODUCTION AND CONCLUSIONS

In 2008, Transportation Technology Center, Inc. (TTCI) installed five concrete and thirteen wood crosstie test zones for in-track testing with various plate hold-down and fastening systems at FAST. One gum and one plastic composite tie zone from a previous test also became a part of the ongoing test. Two hardwood subzones were added in 2009, and one concrete tie test zone was installed in 2011. A total of 24 test zones are currently in test in the 6-degree, 5-inch superelevation curve of the High Tonnage Loop.

In a three-phase program, TTCI is comparing the performance of various crossties and fastener designs to identify problems with current design and material (Phase 1), to quantify the load environment (Phase 2), and to recommend design guidelines (Phase 3).

Phase 1 test results to date indicate that softwood ties (red pine) with a standard AREMA 18-inch tie plate and cut spikes have the highest railhead and rail base deflections under load followed by hardwood ties with cut spikes and an AREMA 18-inch tie plate (18-inch tie plates are sometimes used instead of 14-inch tie plates to increase the load bearing area between the tie and tie plate). Data also shows that thus far in the test, wood ties with elastic fastening systems have track gage strength similar to concrete ties.

Several rolled tie plates on softwood and hardwood ties broke during 350 MGT of heavy axle load (HAL) service life. The design of the tie plate likely contributed to the breakages, along with many broken spikes. Several AREMA standard 14-inch tie plates also broke on plastic ties from lower tie bending stiffness causing higher flexibility of tie plates. No significant failures of elastic fasteners and high strength plate hold-down devices were recorded on wood ties.

Because of frequent cracking, all field side Pandrol and AirBoss insulators were replaced on concrete ties after 250 MGT of HAL traffic.

PROCEDURES

The Tie and Fastener Technical Advisory Group of the Heavy Axle Load Engineering Research Committee recommended current crosstie and fastener test combinations. This included a baseline for ties and fasteners currently in use (14-inch AREMA plates with cut spikes), along with new designs either being considered or being introduced by major railroads. The current test consists of three zones:

Concrete tie zone: Variations with drive-on clip, screw hold-down clip, and some variations of tie pads.

Wood tie zone: Further divided into mixed hardwood and softwood (red pine) subzones. Include cut spike and elastic fastening systems with high strength screw spikes or drive spike as tie plate holding devices and numerous tie plate designs.

Previous tie zone: Two plastic tie subzones and one gum tie zone are from previous tests.

These three zones were further divided into several subzones of various crosstie and fastening system combinations, as Table 1 shows.

Table 1. FAST Crosstie Test Subzones[1]

SUB-ZONE	TIE TYPES	NO. OF TIES	TIE-PLATE	RAIL BASE HOLD DOWN DEVICE	TIE PLATE HOLD DOWN	TONNAGE (MGT)
	Previous Tie Zone					
1	Gum Hardwood[1]	100	AREMA 14"	CS[2]	CS	1143
2	RTI composite	100	AREMA 14"	CS	CS	1050
6	Tie Tek composite	100	AREMA 14"	CS	CS	1500
	Concrete Tie Zone					
2a	CXT	25		Safelok III	_	70
3a	Rocla	25	Epoxied pad	Vossloh clip	_	470
3b	Rocla	28	Std. pad	Vossloh clip	_	470
4	Rocla	50		Pandrol Safelok I	_	470
5a	Rocla	25	Pad with metal plate	Airboss clip	_	470
5b	Rocla	25	All plastic pad	Airboss clip	_	470
	Wood Tie Zone					
0a	Hardwood	50	Pandrol Victor	e-clip, staggered	CS	360
0b	Hardwood	50	Pandrol Victor	e-clip, Inline	DS[3]	360
7	Hardwood	100	MSR	Pandrol e-clip	HS-SS[4]	470
8a	Hardwood	50	Vossloh	Vossloh clip	HS-SS	470
8b	Hardwood	50	Vossloh	Vossloh clip	DS	470
9a	Hardwood	50	NorFast	NorFast clip	DS	470
9b	Hardwood	50	NorFast	NorFast clip	HS-SS	470
10a	Hardwood	50	Pandrol Rolled	Pandrol e-clip	HS-SS	470
10b	Hardwood	50	Pandrol Rolled	Pandrol e-clip	DS	470
11b	Hardwood	50	Leading edge (LE)	Safelok	HS-SS	470
12	Hardwood	100	Airboss	Airboss clip	HS-SS	470
13	Hardwood	100	AREMA 18"	CS	CS	470
10c	Softwood	50	Pandrol Rolled	Pandrol e-clip	HS-SS	470
11a	Softwood	49	Leading edge (LE)	Safelok	HS-SS	470
14	Softwood	100	AREMA 18"	CS	CS	470

[1] Removed from track
[2] CS – Cut spikes, all box anchored, 9/16" pilot holes
[3] DS – Drive spikes
[4] HS-SS – High strength screw spikes

Track Gage Widening Strength

Track gage strength was measured using the Track Loading Vehicle (TLV) and the Light Track Loading Fixture (LTLF).

The TLV applies 33,000 pounds of vertical load and 18,000 pounds lateral load. Figure 1 shows delta gage dynamic (the difference between the loaded and unloaded track gage) TLV measurements at 20 mph after 115, 205, and 255 MGT of traffic. The gum, RTI, and TieTek ties were in test before the current tests, and therefore the measurement cycles are different. Gum ties were removed after 1,042 MGT because of wide gage, tie splitting, and high spike maintenance issues.

In the wood tie zone, the last measurement showed an average delta gage of 0.5 and 0.6 inch for subzones 13 and 14 (ties with cut spikes) respectively. Comparatively, for ties with elastic fastening systems, the last measured average delta gage was only 0.3 inch. This shows that track gage holding capability of wood ties with cut spikes degraded significantly after 255 MGT. In the concrete tie zone, the delta gage measured using the TLV for ties with Vossloh clips was 0.35 inch compared to 0.25 inch for the Pandrol Safelok clips. Early in the test, several screw spikes were found broken and replaced in ties with Vossloh clips. That may have affected the delta gage measurements. The rate of change of delta gage from 115 to 255 MGT was similar for both systems. In general, delta gage values for concrete and wood ties with elastic fastening systems were similar.

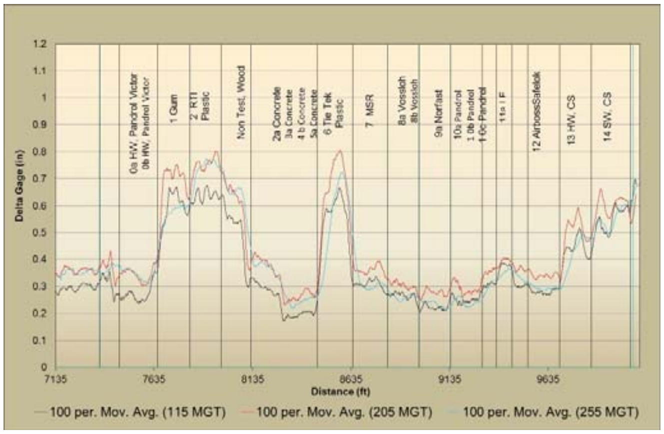

Figure 1. Track Gage TLV Measurements

In the TieTek, RTI, and gum tie zones, up to 0.9 inch of delta gage was recorded. This value shows the effects of the significant amount of HAL tonnage accumulated over these ties. All subzones are still in compliance with FRA Class 4 track gage requirements.

As Figure 2 shows, the LTLF measurements produced similar trends to those measured using the TLV; however, the LTLF system uses half the lateral load (9,000 lb vs. 18,000 lb) and no vertical load. The railhead and base deflection is easured when the LTLF fixture loads the rail in the center of the rail web instead of at the gage line. Rail base measurements provide insight into tie plate hold-down devices, tie plate holes, and crosstie holes. In the wood tie zone, subzones 13 and 14 with cut spikes show higher base values in comparison to other wood tie subzones, suggesting more wear on spikes, tie plates, and crosstie holes. This was verified by removing the tie plates and inspecting the holes.

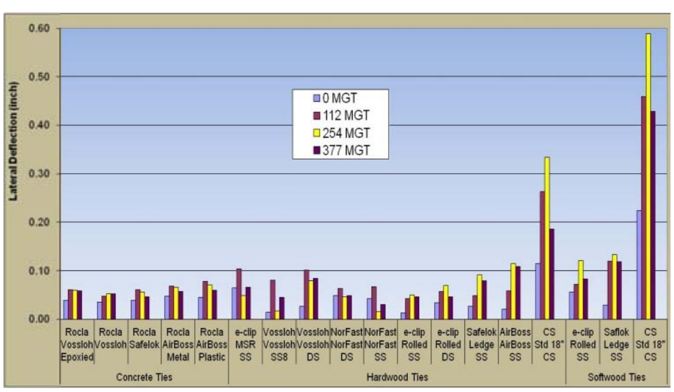

Figure 2. Rail Base Deflections using LTLF

Broken Tie Plates and Spikes

About 8 percent of the Pandrol rolled tie plates were replaced during 350 MGT of traffic in subzones 10a, 10b, and 10c. Most tie plates broke near the field side shoulder along the high rail. These zones also experienced several high-strength screw-pike and drive-spike failures. Subzone 10a experienced the least number of failures, whereas subzone 10c experienced the highest number of failures.

Pandrol rolled tie plates (1/2 to 11/16 inch thickness) are thinner than Pandrol cast tie plates (13/16 to 15/16 inch thickness). Pandrol cast tie plates in other subzones did not experience failures. It appears that the lower tie-plate thickness in subzone 10 may have contributed to the tie-plate breakage. In addition, tie-plate geometry also may have contributed to failures. The tie plates skew relative to the rail base making a point contact at the corner of the shoulder. This condition likely causes a stress concentration. Higher tie plate hold-down failure rate is also likely due to relatively flexible tie plates. Other subzones with the same hold-down systems but tie plates with higher thickness and different geometry did not experience as many failures.

Subzones 1 and 6 both have AREMA 14-inch standard tie plates (9/16 to 3/4 inch thickness) and have accumulated similar tonnage. About 26 percent of the tie plates failed in subzone 6. These failures may be attributed to lower plastic tie stiffness.[2] The modulus of elasticity of solid sawn ties in bending is considerably higher than that found in the plastic ties (by 100 to 200 percent, typically). This may be the reason the tie plates in subzone 1 did not fail. Figure 3 shows typical failures.

Figure 3. Clockwise from top left corner – Broken AREMA 14-inch Tie Plates, Broken Rolled Tie Plate, Screw Spikes with High Neck Wear, and Broken Screw Spikes

Tie-Plate Cutting

Several tie plates broke in two subzones. Before replacing the tie plates, tie-plate cutting depth was measured by using a straightedge and ruler. The data is limited in the sense that measurements were taken only on the rail seats where broken tie plates were found. Figure 4 compares these measurements.

Tie plate geometry and crosstie material were different for the two subzones, but some general conclusions seem appropriate. For example, although at the time of the measurements, the TieTek plastic ties had 4 times higher tonnage, but the tie plate cutting depth was only one-third of that found on the wood ties. Similarly, within the wood tie zone, tie plate cutting on softwood ties was significantly higher than on the mixed hardwood ties.

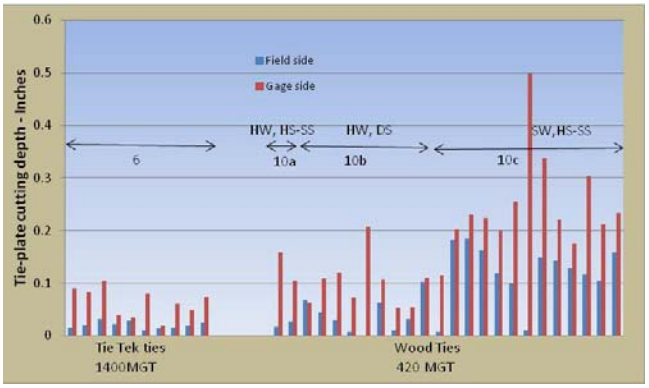

Figure 4. Tie Plate Cutting

Maintenance Logs

The level of maintenance required by a particular crosstie and fastening system is an important factor in the life-cycle cost of track. Maintenance performed on test zones is carefully documented and analyzed. However, to date most of the maintenance work carried out in most subzones is due to rail changes, installation of rail plugs, or rail welding. Removing spikes, plugging holes, and reinstallation generally improve the track gage widening resistance, though not to the level of new ties. The effects of maintenance are generally evident in the test data.

Due to ballast migration from high to low rail in the test curve, all concrete tie subzones, particularly locations close to field welds, required spot ballast regulation. In subzones 4, 5a, and 5b, all insulators were replaced with an updated design at 250 MGT because of a cracking issue. Since then, no cracked insulators have been observed.

In zone 8a, several standard strength screw spikes broke during 250 MGT traffic. All spikes were replaced with high strength screw spikes. Since then, no failures have been observed.

Zone 11a required a very high level of spike maintenance. A total of 103 screw spike redriving occurrences were recorded for 400 high-strength screw spikes in this subzone. Some spikes were redriven many times, and finally the hole was plugged with foam (instead of wood plug) before redriving the spike. Comparatively, zone 11b, with mixed hardwood ties, required only six spikes to be redriven. The cause of high spike maintenance in subzone 11a is being investigated.

FUTURE WORK

The following shows a breakdown of the planned various phases of this project.

Phase 1

1. In order to further enhance the understanding of crosstie and fastener issues, performance monitoring of current tests reported in this *Technology Digest* will continue.
2. After the completion of tests, component maintenance life-cycle costs will be estimated.
3. A detailed analysis of the effects of in-line and staggered shoulders (shoulders that are not in-line) on tie and tie plate skewing has been planned.
4. Techniques to reduce tie plate cutting, using composite materials, will be investigated.

Phase 2

1. Based on the current tests and those conducted in the past, a crosstie and fastener performance index will be developed.
2. Load environment of components with various tie materials and tie plate designs will be measured.
3. Effects of individual component stiffness on the total performance of crosstie and fasteners will be studied.

Phase 3

Recommended design guidelines will be developed and will include:

1. Minimum bending stiffness for composite ties
2. Minimum tie plate dimension (thickness, length, and width)
3. Optimum distance of hold-down devices from rail base

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1. Reiff, Richard. November 2008. “2008 FAST Tie and Fastener Test, As Built Status Report,” Research Summary RS-08-003, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO.

2. Gonzales, Kari, et al. February 2008. “Evaluation of Tie Plate Cracking on Composite Ties,” *Technology Digest* TD-08-009, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO.