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# Tie and Fastener System Gage Restraint Performance at FAST

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## Summary

To better understand the performance of the tie and fastener system under heavy axle loads, Transportation Technology Center, Inc. (TTCI) continues to perform testing on a variety of tie and fastener test zones at the Facility for Accelerated Service Testing (FAST).

The test section includes zones of hardwood ties with and without elastic fastening systems, softwood ties with and without elastic fastening systems, two zones of composite ties with cut spike and AREMA plate-fastening systems, and two varieties of concrete tie fastening systems (one with narrower insulators and one with wider insulators). The test section is installed in Section 25 at FAST, a 6-degree curve.

Specifically, TTCI is documenting common failure modes and assessing performance of these systems through gage restraint measurement system (GRMS) and lateral track loading fixture (LTLF) testing.

The failure mechanisms observed for the various tie and fastener systems are:

- Severe plate cutting in softwood ties (for both elastic fasteners and cut spikes) through 757 MGT.
- Raised cut spikes in composite ties, requiring re-driving.
- Screw spikes appear to fail more predominantly by breaking (instead of rising), especially for plate designs that place the gage side screw spikes closer to the rail.
- Drive spikes appear to fail more predominantly by rising (instead of breaking).
- Plate cutting corresponds to gage side hold-down condition — more field side plate cutting was observed on a given tie if the gage side hold-down spikes were in poor condition or had failed.
- Broken field side insulators were observed on Airboss and SAFELOK I concrete tie fastening systems.

GRMS and LTLF testing are two ways to apply a gage widening load to the track and measure the tie and fastener systems ability to resist gage widening. The GRMS deployed for testing was the Federal Railroad Administration's DOTX218 (T-18) research vehicle. LTLF testing has been performed with loading applied at the rail web and also with load applied at the railhead.

Results of the GRMS and LTLF testing are:

- Unloaded gage on the Airboss and SAFELOK I concrete tie fastening system and on all softwood tie zones was higher than any of the hardwood tie zones. This is likely due to broken field side insulators in Airboss and SAFELOK I zones and to plate cutting on the softwood ties.
- The GRMS delta gage and LTLF gage widening were highest in the composite tie and softwood tie zones, especially on cut spike and AREMA plate-fastening systems.
- The hardwood tie and elastic fastener zones perform similarly to the concrete tie/fastener systems in regards to GRMS delta gage.

The ongoing testing allows common failure modes to be documented and observed in performance testing data. Future work in this area will seek to continually refresh the test section with tie and fastener systems representative of industry state of the art. Results of this work will ultimately be fed into cost-degradation modeling, which will allow a measureable benefit to be attributed to higher performance tie and fastener systems and ultimately give the railroads a better tool for tie and fastener purchasing and maintenance planning.



**INTRODUCTION**

The ties and fasteners of conventional ballasted track act together as a system to transfer vertical and lateral load applied at the wheel-rail interface into the ballast, and to maintain sufficient track geometry, particularly track gage. The tie and fastener system, depending on its design can fail in a multitude of ways, inhibiting one or more of its primary functions. These failures typically occur at the interface of two of the system’s components. As part of the Association of American Railroads’ Strategic Research Initiative Program to assess tie and fastener system performance, LTLF and GRMS testing was conducted on a variety of tie and fastener designs. Failure modes of the various tie and fastener systems have also been monitored and documented to compare with these test results.

**TEST SETUP**

In 2008, TTCI installed five concrete and thirteen wood crosstie test zones in Section 25 at FAST.<sup>1</sup> Two hardwood tie and elastic fastener test zones were subsequently installed in 2009. Two existing composite tie test zones (installed in 2000 and 2004, respectively) were also incorporated into this test. The variety of ties and fasteners selected for the test was recommended by the Tie and Fastener Technical Advisory Group. Table 1 shows the zone number, tie type, fastener type, and tonnage for each of the test zones. The tonnage reported in Table 1 corresponds with time of the test results presented below.

These tie and fastener test zones are installed in Section 25 of the High Tonnage Loop at FAST. Section 25 is a 6-degree curve with 5 inches of superelevation. Heavy axle load tonnage is accumulated on the test zones through a consist of 315,000-pound (39-ton axle load) cars. The train is operated at 40 mph, with about a 2-inch overbalanced speed for the curve helping to accelerate component wear, especially on the high rail. Track geometry in Section 25 is maintained to FRA Class 4 track safety standards.

Brands of some suppliers providing components for this test have since been acquired by other companies. Two suppliers — RTI and NorFast — are no longer in business.

**Observed Failure Modes**

The primary failure mode of the two composite tie zones has been raised cut spikes. As they have accumulated tonnage, maintenance has been performed to re-drive the cut spikes. In September 2014, the gage side low rail spike holes in Zone 6 needed to be plugged in order to retain spike hold-down capacity as loose spikes were being observed. Structural failure modes (e.g., center cracking or cracking at spike holes) in either of the composite tie test zones have not been observed.

Based on observations of the most recent inspection, screw spikes tend to fail more predominantly through breaking, and drive spikes appear to fail more predominantly through rising.

Screw spike breakage tends to occur at the interface of the threaded and nonthreaded area of the spike. Zones 11a and 12 had the greatest percentage of broken or missing gage side screw spikes. The screw spikes for both of these fastening systems are located closer to the base of the rail than other tie plate designs (such as Zone 7), as Figure 1 shows.

**Table 1. Tie and Fastener Test Zones**

Test Zone	MGT as of 3/30/15	No. of Ties	Tie Type	Tie Plate	Rail Fastener	Hold-Down Fastener
0a	820	50	Mixed Hardwood	18" Pandrol Victor Rolled	eClip	Cut Spike
0b	820	50	Mixed Hardwood	18" Pandrol Victor Rolled	eClip	Drive Spike
1	735	100	Mixed Hardwood	14" AREMA Rolled	Cut Spike	Cut Spike
2	1510	100	RTI Composite*	14" AREMA Rolled	Cut Spike	Cut Spike
3a	935	25	Rocla Concrete	-	Vossloh W30**	-
3b	935	28	Rocla Concrete	-	Vossloh W40**	-
4	935	50	Rocla Concrete	-	Pandrol Safelok	-
5a	935	25	Rocla Concrete	-	Airboss	-
5b	935	25	Rocla Concrete	-	Airboss	-
6	1975	100	TieTek Composite	14" AREMA Rolled	Cut Spike	Cut Spike
7	935	100	Mixed Hardwood	16" Cast Cleated	eClip	HS Screw Spike
8a	935	50	Mixed Hardwood	18" Vossloh Rolled	Vossloh BT30	HS Screw Spike, SS8
8b	935	50	Mixed Hardwood	18" Vossloh Rolled	Vossloh BT30	Drive Spike
9a	935	50	Mixed Hardwood	16" NorFast, Cast*	NorFast	Drive Spike
9b	935	50	Mixed Hardwood	16" NorFast, Cast*	NorFast	HS Screw Spike
10a	935	50	Mixed Hardwood	16" Pandrol, Rolled HS Steel	eClip	HS Screw Spike
10b	935	50	Mixed Hardwood	16" Pandrol Victor Rolled	FastClip	Drive Spike
10c	935	50	Softwood (Red Pine)	16" Pandrol Victor Rolled	FastClip	HS Screw Spike
11a	935	49	Softwood (Red Pine)	18" Leading Edge, Cast	Safelok	HS Screw Spike
11b	935	50	Mixed Hardwood	18" Leading Edge, Cast	Safelok	HS Screw Spike
12	935	100	Mixed Hardwood	16" Airboss, Cast	AirBoss	HS Screw Spike
13	935	100	Mixed Hardwood	18" AREMA Rolled	Cut Spike	Cut Spike
14	935	100	Softwood (Red Pine)	18" AREMA Rolled	Cut Spike	Cut Spike

\*RTI and NorFast are no longer in business

\*\*Replaced original W14 clips with W30 and W40 on 1/22/13

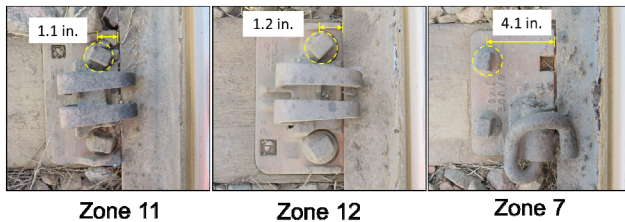


Figure 1. Zones 11 and 12 Location of Gage Side Screw Spikes

This observation suggests that the location of the spike on the plate plays a role in the forces acting on the spike and spike related failure modes.

The three softwood tie zones (10c, 11a, and 14) have exhibited severe plate cutting through 757 MGT. Zone 10c, with 16-inch plates, has shown the largest amount of plate cutting with approximately 1/2 inch on the high rail and 1/4 inch (uniformly) on the low rail. The 18-inch plates in Zones 11a and 14 appear to have mitigated the plate cutting to some degree with approximately 1/4 inch of plate cutting observed on the high rail. In general, for all wood and composite zones, individual ties with a poorer gage side hold-down condition (missing, loose, or broken spikes) tended to have higher severity of plate cutting.

The most recent inspection in September 2014 indicated that roughly 20 percent of the high rail field side insulators in Zones 4 and 5 (Airboss and SAFELOK I fasteners) were broken or missing. No broken insulators or clips were noted in Zone 3 (Rocla ties with Vossloh fastening system). It should be noted that the insulators in Zone 3 are wider and provide more potential contact area for the lateral load to be transferred to the tie. No structural cracking or failure was noted for any of the concrete ties.

No significant breakage of elastic clips in either the wood or concrete tie zones has been observed.

### Lateral Track Loading Fixture Testing

To quantify each tie and fastener combination’s ability to resist gage widening, LTLF testing was performed, most recently, in March 2014. LTLF testing has been conducted periodically since the installation of the tie and fastener test zone in 2008. The LTLF applies a localized gage widening load to the track. Railhead and rail base deflections are measured on each rail for a given load.

Traditionally, the LTLF fixture has applied the gage widening load at the web of the rail. The application of load at the web is thought to exercise failure modes such as spike kill (lateral spike resistance) and spike breakage.

Alternatively, TTCI has experimented with an LTLF device that applies load at the head of the rail, specifically on the gage line of the two rails. Head applied load simulates a more severe lateral load environment, and, due to an increased applied moment, better exercises the hold-down capacity of the fastening system, particularly on the gage side of the rail.

Figure 2 shows the LTLF device in a (a) web applied load configuration and in a (b) head applied load configuration. In 2014, data was collected for both web and head applied loads.

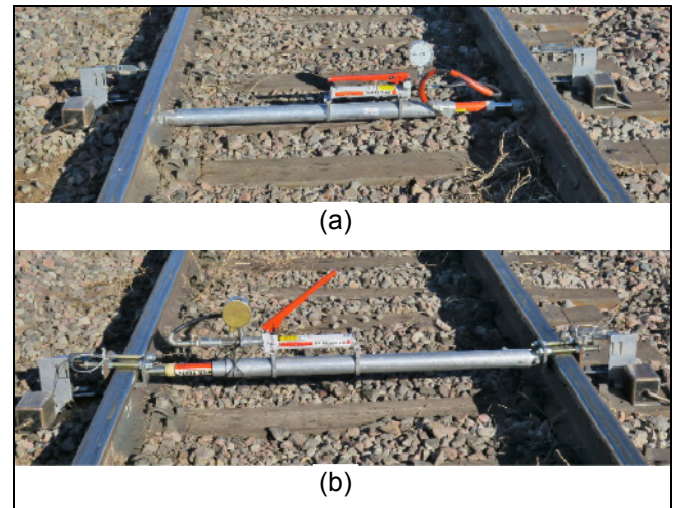


Figure 2. LTLF Configured for (a) Web Applied Load and (b) Head Applied Load

### Gage Restraint Measurement System Testing

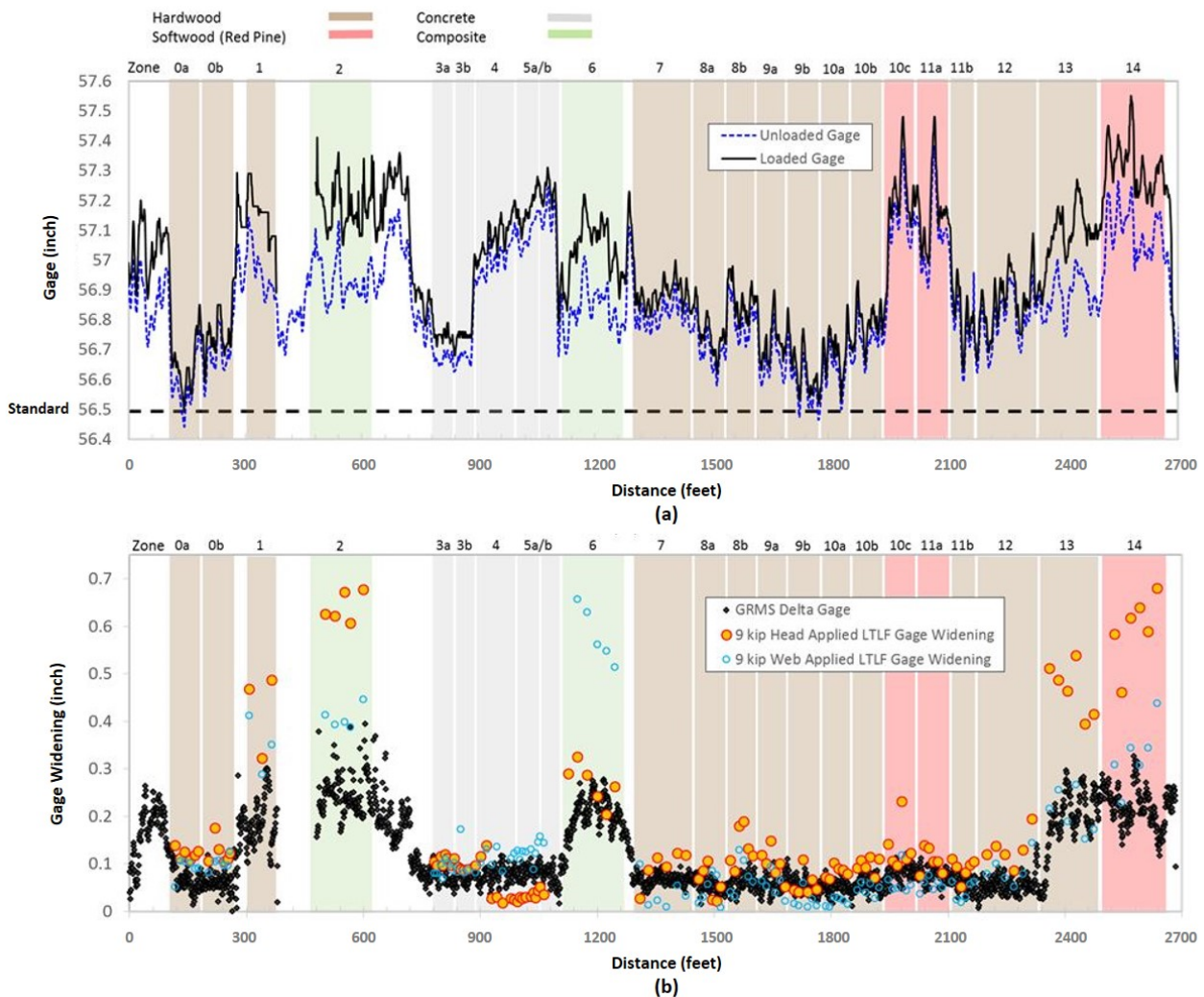
In the spring of 2014, one day prior to LTLF testing, in-track GRMS testing was conducted at FAST using the DOTX218 (T-18) research vehicle. The T-18 car has a deployable axle used to apply an in-motion gage-widening load to the rails.

For the GRMS run, an average lateral load of 13.6 kips (with a standard deviation of 0.23 kips) and an average vertical load of 18.9 kips (with a standard deviation of 0.35 kips) were applied to the rails, acting to widen the gage. This equates to an average L/V ratio of about 0.7. The vehicle traveled self-propelled at a speed ranging from 20 to 29 mph. The car’s loaded gage and unloaded gage measurements were analyzed.

### RESULTS AND CONCLUSIONS

Figure 3(a) shows the GRMS loaded gage data, overlaid on the unloaded (static) gage data from the same run. Figure 3(b) shows the GRMS delta gage (loaded minus unloaded gage) plotted alongside the LTLF gage widening (taken at approximately the gage line of the track) for the 9-kip head applied load and the 9-kip web applied load. For both figures, the background color for each zone indicates the tie material for that zone as indicated in the legend. The zone numbers are indicated on the upper x-axis.

Many of the failure modes observed in the various tie and fastener zones are visible in the GRMS and LTLF performance test results. Unloaded gage tended to be higher in Zones 4 and 5 as well as in the softwood tie zones of 10c, 11a, and 14. This is likely related to the broken field side insulators on the Airboss and SAFELOK I fasteners and the severe plate cutting observed in the softwood tie zones.



**Figure 3. (a) Unloaded (static) Gage and GRMS Loaded Gage for the Tie and Fastener Test Zones and (b) GRMS Delta Gage vs. the 9-kip Head Applied Load and Web Applied Load LTLF Gage Widening**

GRMS delta gage was significantly higher for the zones with cut spike rail fasteners (Zones 1, 2, 6, 13, and 14). In general, the GRMS delta gage was below 0.1 inch for all wood tie and elastic fastener zones regardless of plate size, clip type, or hold-down fastener. Similar performance, in this regard, is seen in the concrete tie zones.

In general, the web applied LTLF load appears to better simulate the T-18's GRMS applied load. For most zones, the LTLF gage widening due to the web applied load tends to be lower than that due to the head applied load. However, for Zone 6, the TieTek composite ties, and Zones 4 and 5, concrete ties with Airboss and SAFELOK I fasteners, the gage widening due to the web applied load exceeded that due to the head applied load. These results may suggest that the web applied LTLF better exercises rail translation related failure modes such as the loose spikes observed in Zone 6 and the broken field side insulators observed in Zones 4 and 5. Similarly, the head applied LTLF may better exercise rail rotation related failure modes such as raised gage side cut spikes or reduced elastic fastener toe load.

Zones 0a (18-inch Victor plate and cut spike) and 0b (18-inch Victor plate and drive spike), appear to be performing similarly after 646 MGT. The gage side hold-down fastener condition on wood and composite ties appears to correspond with the severity of plate cutting observed on the field side of the plate. The cleated plates in Zone 7 do not appear to be providing any additional gage restraint (unloaded or loaded).

## FUTURE WORK

The results of this testing will be used in a cost-degradation analysis, which will ultimately allow a measurable benefit to be attributed to higher performance tie and fastener systems and provide member railroads with a better tool for tie and fastener purchasing and maintenance planning.

## REFERENCE

1. Reiff, Richard. 2008. "2008 FAST Tie and Fastener Test As Built Status Report." Research Summary RS-08-003, AAR/TCI, Pueblo, Colorado.

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