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Concrete Tie Testing at FAST to Address Improved Track Strength

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Summary

Transportation Technology Center, Inc. (TTCI) continues to study a variety of improved performance concrete tie designs. To better understand performance differences between these improved designs and conventional concrete ties, performance testing has been conducted at the Facility for Accelerated Service Testing (FAST).

The test section includes five zones of concrete ties including one control zone at 24-inch spacing, two zones of conventional ties with elastic under-tie pads at 24-inch spacing, one zone of conventional ties at 20-inch spacing, and one zone of half-frame ties, a larger, heavier tie with increased bearing area at the rail seat and ballast interfaces. The test section is installed in a 5-degree curve in Section 3 at FAST.

Specifically, TTCI is documenting failure modes and assessing performance of these systems using track geometry and gage restraint measurement system (GRMS) data. Track geometry, particularly track surface, allows the settlement, or differential settlement within the tie zones to be characterized. GRMS allows the gage restraint of the various tie systems to be characterized under an in-motion gage-widening load.

Results thus far include:

- The five test zones have accumulated 893 MGT to date
- All zones continue to maintain track surface acceptable under Federal Railroad Administration (FRA) Class 4 limits
- None of the zones have required track surfacing or alignment since installation
- Historical track geometry data has shown no significant differences between the zones
- GRMS results showed no significant differences in gage restraint between the zones with delta gage measurements less than 0.15 inch for all zones.
- Ballast migration is evident in one of the under-tie pad zones (Zone 3) and has required ballast regulation approximately every 100 to 200 MGT, likely preventing alignment defects.
- Broken insulators continue to be a primary failure mode for multiple fastening systems
- No significant tie cracking has been observed

In spring 2014, FRA’s T-18 research vehicle was used for track geometry and GRMS testing at 650 MGT. Future work in this area will include additional alternative concrete tie designs as well as more specific testing to address the performance of concrete tie under-tie pads, specifically their dynamic performance.

This in-track testing is being conducted as part of an ongoing Association of American Railroads’ Strategic Research Initiative to improve tie and fastener performance. Alternative track designs may be necessary in the future as demands increase for higher tonnage, higher reliability, and higher speed trains.

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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. The tie and fastener system can fail in a multitude of ways, inhibiting one or more of its primary functions, ultimately manifesting itself in track geometry defects.

As part of the AAR's Strategic Research Initiatives Program to improve tie and fastener performance, various concrete tie test zones have been installed and are being tested at FAST in order to address improving overall track strength.

The test zones currently being studied seek to improve overall track strength in the lateral, longitudinal, and vertical axes of the track.

TEST SETUP

In 2009, TTCI installed five improved track strength test zones (Figure 1).

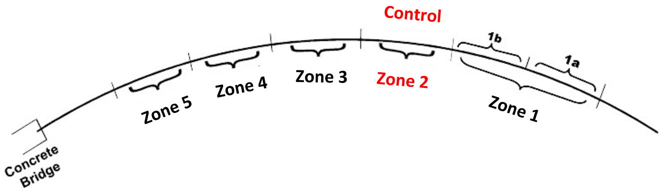

Figure 1. Concrete tie test zones in Section 3 at FAST

Zone 1 is comprised of 190 half-frame ties, a heavy duty tie with increased bearing area at the rail seat and ballast interfaces. The half-frame ties being tested also include an elastic under-tie pad (UTP) cast into the bottom surface. Zone 1a has four rail fasteners per tie and Zone 1b has six rail fasteners per tie. Zone 2 is a control zone of 100 conventional concrete ties. Zone 3 has 100 conventional concrete ties with a factory installed (cast-in) elastic under-tie pad. Zone 4 contains 100 conventional concrete ties with a field installed (epoxied) elastic under-tie pad. Zone 5 incorporates 64 conventional concrete ties without elastic under-tie pads. The ties are spaced at 24 inches in Zones 1-4 and at 20 inches in Zone 5.

These tie and fastener test zones are installed in Section 3 of the High Tonnage Loop (HTL) at FAST. Section 3 is a 5-degree curve with approximately 4 inches of superelevation. Heavy axle load tonnage is accumulated on the test zones using a train consist of 315,000-pound (39-ton axle load) cars. The train is operated at 40 mph, about 1.7 inches of overbalanced speed for the curve helping to accelerate component wear, particularly on the high rail fastening system. Track geometry in Section 3 is maintained to FRA Class 4 track safety standards. Gage face and top of rail lubrication is used in Section 3.

Table 1 gives the component details for the concrete tie test zones.

Table 1. Improved Track Strength Concrete Tie Test Zones

Test Zone	MGT as of 6/1/15	No. of Ties	Tie Type	Tie Pad	Rail Fastener	Spacing (in.)
1	893	190	Half Frame Tie with UTP	Rubber	SKL type clamp*	24
2	893	100	Scalloped Conventional Concrete Tie	Mixed**	Mixed**	24
3	893	100	Unscalloped Conventional Concrete Tie with UTP	3-piece abrasion resistant assembly	captive elastic clip	24
4	893	100	Unscalloped Conventional Concrete Tie with UTP	TPU with steel abrasion plate	e-clip type	24
5	893	64	Scalloped Conventional Concrete Ties	TPU with steel abrasion plate	McKay type	20

***95 ties with six clamps per tie (two gage side and one field side) and 95 ties with four clamps per tie (one gage side and one field side)**

****Zone 2 contains combinations of e-clip type, McKay type, and other captive elastic rail fasteners and either 3-piece abrasion resistant pad assemblies, thermoplastic polyurethane (TPU) tie pads, and TPU tie pads with steel abrasion resistant assemblies.**

To characterize the load environment of track components, instrumented wheelsets (IWS) are regularly used to measure wheel-rail forces. The IWS are installed on a typical FAST car and measurements of vertical and lateral force are recorded at track speed (40 mph). Table 2 summarizes the IWS measurements throughout Section 3 taken in the fall of 2014.

Table 2. IWS Forces Measured in Section 3

		Leading Axle			Trailing Axle		
	Rail	Avg.	Std. Dev	Peak	Avg.	Std. Dev.	Peak
Vertical Forces (kips)	High	45.4	4.1	72.1	44.8	3.5	77.9
	Low	35.1	4.2	54.6	33.8	4.1	50.6
Lateral Forces (kips)	High	5.8	4.3	28.9	2.5	1.8	14.8
	Low	3.6	2.8	14.6	1.2	1.6	10.4

TRACK GEOMETRY

As the tie and fastener's primary responsibility is to maintain sufficient track geometry, namely gage, alignment, and surface, a practical means to compare tie and fastener performance over time is through these track geometry metrics. Higher performing tie and fastener systems should demonstrate higher overall track quality (i.e., lower variations in gage, surface, and alignment) compared to poorer performing systems throughout their lifecycle.

A track geometry run was conducted over the zone using the FRA's DOTX218 (T-18) research vehicle in spring 2014.

Figure 2 shows the box plot of low and high rail surface measurements from this geometry data. Figure 3 shows the box plot of low and high rail alignment. Both surface and alignment measurements are shown for a 31-foot chord. Any transition effects between the zones were excluded from the analysis.

These recent results suggest no significant difference in surface or alignment is being observed between the five zones. In practice, this result is also apparent, as none of the five zones have required surfacing or alignment since their installation. As noted above, however, the ballast migration in Zone 3 likely would have resulted in alignment defects if no maintenance was conducted.

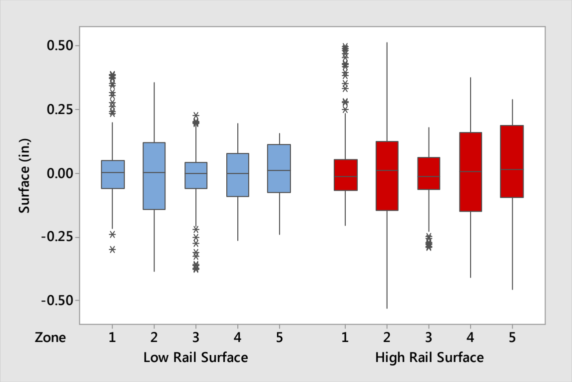

Figure 2. Box plot of low and high rail surface

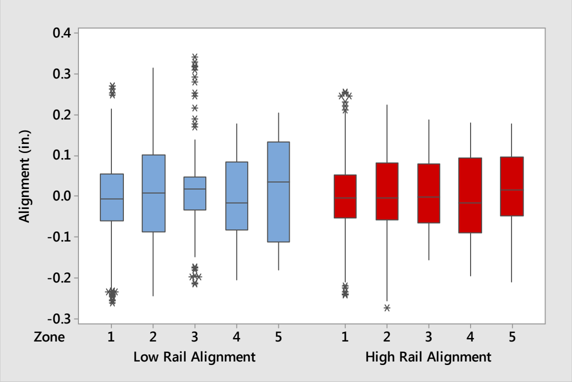

Figure 3. Box plot of low and high rail alignment

Initial forecasts of track surface degradation predicted significantly higher performance for the half-frame ties, specifically lower track surface roughenss.[1] The most recent geometry testing, however, shows that this specific benefit has not materialized yet. Ballast sampling and imaging data have suggested that the half-frame ties are reducing ballast degradation beneath the tie compared to the control, Zone 2.[2] This may ultimately affect track surface as more tonnage is accumulated.

OBSERVATIONS AND MAINTAINENCE

Track geometry measurements thus far have not indicated sufficiently high enough surface or alignment deviations to warrant surfacing of the track. Localized spots have been tamped after unrelated rail or weld repair.

Ballast migration in Zone 3 has been evident throughout the test. As Figure 4 shows, migrating ballast (from the high rail to the low rail) results in the reduction in shoulder ballast on the outside of the ties. This reduces the lateral restraint of the track and if left unmaintained, may result in track alignment defects, particularly as rail temperatures increase. Ballast migration in Zone 3 has been addressed with regulating on five separate occasions since installation at roughly 100 to 200 MGT intervals.

Figure 4. Typical ballast migration observed in Zone 3, reducing the lateral restraint provided by the high rail shoulder

Superficial shallow cracks in all five tie zones have been observed, but no significant structural cracking has been recorded. Maintenance records do not indicate replacement of any test ties due to cracking. Zone 5 insulator failures have warranted spot replacement on four occasions at approximately every 200 MGT. Zone 2 insulator failures have warranted spot replacement on two occasions since installation at approximately every 400 MGT. Zones 3 and 4 have had insulators replaced more sparingly. The insulator failures observed thus far are consistent with those seen in similar fastening systems being tested on a 6-degree curve at FAST.[3] It does not appear that the tighter 20-inch spacing in Zone 5 is reducing the occurrence of insulator failures compared to similarly designed fastening systems spaced at 24 inches. Insulators have been replaced when track inspector and test engineers deemed necessary. The guide block type insulators on the half-frame ties in Zone 1 have not shown any failures. Figure 5 shows two common insulator failures in Zone 5 (left) and in Zone 2 (right).


(a) (b)

Figure 5. (a) A Common Insulator Failure on a McKay type fastener in Zone 5 and (b) A Common Insulator Failure on an e-clip type fastener in Zone 2.

Rail seat abrasion has not been observed as a failure mode, consistent with historical observations at FAST. Tie pads without abrasion plates (a portion of Zone 2) have shown some minimal wearing into the rail seat surface.

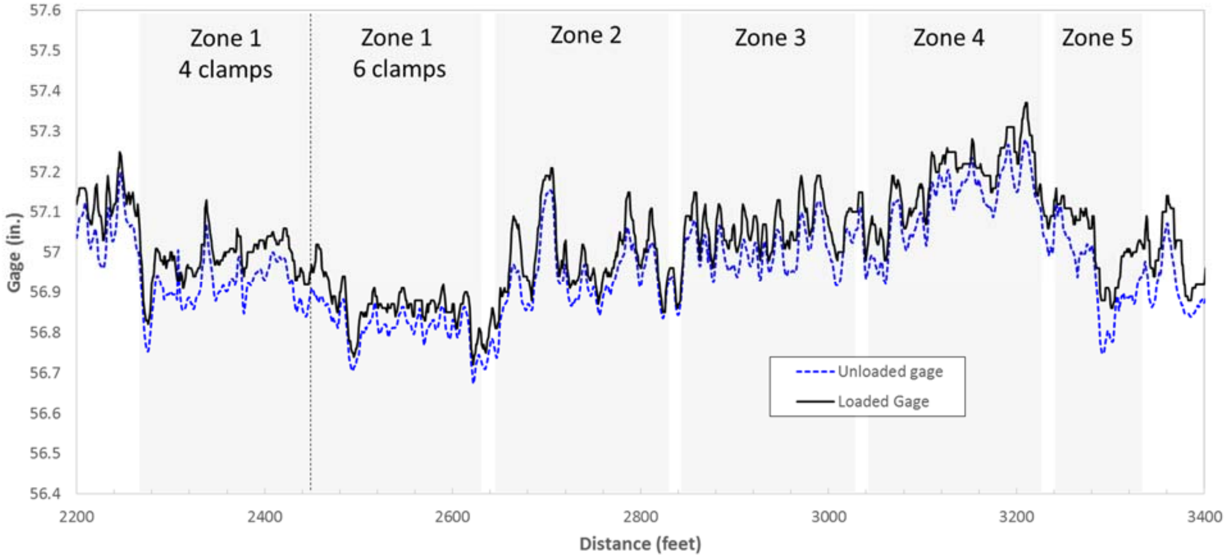

Figure 6. Unloaded (static) Gage and GRMS Loaded Gage for the Concrete Tie and Fastener Test Zones in Section 3

GAGE RESTRAINT

To quantify each tie and fastener's ability to resist gage widening, gage restraint measurement system (GRMS) testing continues to be performed throughout the test. In spring 2014, at 650 MGT, GRMS testing was conducted at FAST using the T-18 car, which 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 0.29 kips) and an average vertical load of 18.9 kips (with a standard deviation of 0.46 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 of 28 mph. The car's loaded gage and unloaded gage measurements were analyzed. Figure 6 shows the unloaded gage plotted against the loaded gage for each of the five test zones.

The unloaded gage measurements ranged from 56.7 inches to 57.2 inches throughout all five zones, a range of 0.2 to 0.7 inch greater than standard gage of 56.5 inches; i.e., the nominal gage at installation. It is estimated that rail side wear in Section 3 accounts for less than 0.1 inch of the gage widening observed throughout the test zone since installation.

As expected, the elastic fasteners provided limited gage widening under the GRMS applied load. Delta gage throughout the five test zones was generally between 0.05 and 0.1 inch. These results are consistent with GRMS results for other concrete tie and elastic fastener systems at FAST under the same loads. The added clamp on the gage side of the rail in the second half of Zone 1 appears to have provided slight increase in gage restraint compared to the first half of the zone with only one gage side clamp.

CONCLUSIONS AND FUTURE WORK

The results of testing thus far have indicated no differential performance in regards to track surface. Comprehensively, no zone has shown enough differential settlement to warrant surfacing maintenance. It is likely that additional tonnage is needed at FAST for differences in track surface to become more apparent, particularly because of the strong support conditions characteristic of the HTL. Differential performance may be more observable on poorer support conditions. Comparing the track alignment between the zones should take into account the additional ballast regulating performed in Zone 3.

Broken insulators, particularly in Zone 5, have been a significant failure mode. Zones 2, 3, and 4 have also shown insulator failures, but to a lesser degree.

The most significant result thus far has been the recurrent ballast migration observed in Zone 3. This observation suggests that the design of the under-tie pad, particularly its dynamic characteristics, may have an effect on track geometry performance. Under-tie pads add an elastic layer to stiffer track structures and have the potential to reduce ballast degradation in these environments, but dynamic performance of the entire track system needs to be considered. Future work will specifically address under-tie pad performance to augment the results thus far.

Moving forward, TTCI will continue to incorporate into the test viable alternative concrete tie designs that address improved track strength.

REFERENCE

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