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Performance of Rail Fastening Systems on an Eastern Mega Site Open-Deck Bridge

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Summary

Transportation Technology Center, Inc. is monitoring the performance of rail fasteners specifically on an open-deck bridge and its approaches at the eastern mega site to complement the ongoing, long-term Crosstie & Fastener Test in open-track at the Facility for Accelerated Service Testing (FAST), Pueblo, Colorado. The fastening systems have been in service on the mega-site bridge since 2010 with more than 230 MGT of heavy axle load traffic.

The test zones where the fastening systems are installed differ in a number of ways; e.g., tie plate size, rail clip type, number and type of plate-to-tie hold-down hardware, all of which may affect performance. This type of test makes it challenging to attribute a given performance characteristic to a specific component, but provides guidance regarding the anticipated serviceability of each system under similar conditions.

The three test systems are (1) Pandrol 16-inch cast plate with screw spikes, and cut spikes and e-clips, (2) Vossloh 16-inch rolled plate with screw spikes and rail clips, and (3) Pandrol 18-inch Victor rolled plate with cut spikes and e-clips.

A modified version of the lightweight track loading fixture (LTLF) was used to measure the gage widening strength of the tie and fastener system.

OBSERVATIONS AND FINDINGS

- System 3 widened 2.4 times more at the railhead and 3 times more at the rail base than System 1 under the 6-kip LTLF gage spreading load in test zones on the bridge. System 3 on the bridge also had the highest loaded gage widening ratio as measured by FRA's T-18 car. Maximum gage widening is still 0.2 inch at 230 MGT. Results will be reported as more tonnage is accumulated.
- The difference between high and low railhead displacement was highest in System 3 on the bridge; 2.4 times more displacement on the high rail.
- One test zone became a hybrid over the course of the test with System 2 on the low rail and System 3 on the high rail, an opportunity to evaluate the performance of the two systems in the different curve environments. The railhead displacement measured on the high rail was 4.6 times higher than the low rail, where the rail lateral stiffness (Δforce/Δdisplacement) was 3.5 higher.
- The 2014 results indicate almost twice higher rail lateral stiffness in System 1 than in System 3 on the bridge for both the high and low rails.
- Gage spreading performance of systems 1 and 3 (bridge zones vs. approach zones), where the bridge zones have under-plate rubber pads and the approach zones do not: (a) Comparable performance on the bridge and at the approach for System 1 and (b) Better performance at the approach than on the bridge for System 3. Higher plate-to-tie clamping force of System 1 with screw spikes may provide higher strength in the more resilient bridge zone.
- System 2 rail clip bolts fractured; whereas none have been reported at FAST. A System 1 tie plate experienced a structural crack; similar to the failure mode seen at FAST.

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INTRODUCTION

Three different rail fastening systems were installed between September 2010 and November 2010 on the Norfolk Southern (NS) Railway, at Wabun, Virginia, as part of the jointly funded Association of American Railroads and Federal Railroad Administration Heavy Axle Load Revenue Service Test Program. The test continues after more than 230 MGT of traffic. The test is being conducted to document the performance of these systems in the unique environment of an open-deck bridge and its open-track approaches.

TEST ENVIRONMENT

The test is being conducted on a multi-span, 525-foot-long open-deck bridge with a newly installed wood-tie deck (15 inch on center spacing) in a 6-degree curve with a 0.66-percent grade.

Test zone 3a was regaged 8 MGT after the start of the test to correct inadvertent wide-gage installation. System 3 is, in effect, a second installation on the relatively new ties (43 MGT) of test zone 2 (Figures 5-8).

TEST ZONES AND COMPONENTS

Table 1 describes the test zones, components, and their location on the bridge.

Table 1. Test Zones and Components

Fastening System	Test Zone (No. of ties/track feet)	Plate Size	Hold Down	Rail Fastener
Test Zones 1a (approach) and 1b (bridge) Pandrol 16” Cast Plate West End	30 ties in the open-track approach/49’ @ 19.5” spacing AND 100 ties on the bridge/125’ @ 15” spacing (Total: 130 ties/174’)	16” L x 7.75” W	High Strength Screw Spikes	e-Clip
Test Zone 2 (bridge) Vossloh BTE-30 16” Rolled Plate	90 ties on the bridge/113’ @ 15” spacing	16” L x 8” W	High Strength Screw Spikes	Skl-30
Test Zones 3a (bridge) and 3b (approach) Control Zone – Pandrol 18” Victor Rolled Plate East End	150 ties on the bridge/188’ @ 15” spacing AND 30 ties in the open-track approach/49’ @ 19.5” spacing (Total: 180 ties/237’)	18” L x 8” W	Cut Spikes	e-Clip

Test Zones — As Installed

Table 2 lists the test zones, as installed, to describe the differences and conditions that may affect system performance. The number and configuration of the plate to tie hold-down fasteners were not specified. It was left to the bridge department to design as they deemed appropriate for this special application. Under-plate rubber pads, an NS standard component on open-deck bridges, were installed throughout the bridge (Figures 1, 2 and 3). Under-tie pads were not installed in the approach test zones.

Table 2. Test Zones, Differences, and Conditions

	Test Zones 1a (approach) and 1b (bridge) Pandrol Cast Plate System West End	Test Zone 2 (bridge) Vossloh BTE-30 System	Test Zones 3a (bridge) and 3b (approach) Pandrol Victor System East End
Tie Plate	16”	16”	18”
Rail Clip	e-clip	SKI-30	e-clip
Rail Base Shoulder	Cast, part of the plate	Rolled plate	Swaged into the rolled plate
Rail Clip Location	Directly opposed	Directly opposed	Diagonally opposed
Plate to Tie Hold Down	Screw Spikes: 2 field side, 2 gage side Cut Spikes: 1 field side, 1 gage side	Screw Spikes: 2 field side, 2 gage side Cut Spikes: 1 field side	Cut Spikes: 3 field side, 2 gage side
Test Zone Location	On the bridge and open-track approach	On the bridge only	On the bridge and open-track approach
Tie Spacing	15” on the bridge/19.5” open-track approach	15” on the bridge only	15” on the bridge/19.5” open-track approach
Under-Plate Rubber Pads	Bridge zone only, none in approach zone	Yes	Bridge zone only, none in approach zone

Figure 1. Pandrol 16-inch Cast Plate System

Figure 2. Vossloh 16-inch Rolled Plate BTE-30 System

Figure 3. Pandrol 18-inch Rolled Plate Victor System

GAGE STRENGTH

The gage strength (resistance to gage spreading force) of each test zone was measured using a LTLF, which applies gage spreading loads and measures the resulting rail displacement.

Evaluation of LTLF Data Resolution at FAST

An evaluation was conducted at FAST before the first LTLF test at Wabun to determine the possibility of achieving better resolution of fastening system gage strength performance results by applying the gage spreading load to the head of the rail instead of to the web, below the neutral axis (traditional method). As shown in Table 3, where elastic fastener test zones 4 and 5 are compared, the gage spreading differences are greater when the gage spreading load is applied to the head of the rail for each given load. As an added benefit, the differences (resolution) between test zones become less as the gage spreading load was increased suggesting the clips were approaching their elastic limit. This finding allows the test to be conducted at the lower gage spreading load of 6 kips resulting in better test data resolution.

Table 3. Percent Difference in Gage Strength between FAST Test Zones 4 and 5, Load applied at the Railhead vs. Low on Rail Web

Gage Spreading Load	9 kips		8 kips		6 kips	
Location Applied Load	Rail Head	Rail Web	Rail Head	Rail Web	Rail Head	Rail Web
Percent Difference in Gage Strength Zone 4 vs. 5	18%	4%	22%	7%	28%	12%

LTLF Static Gage Strength Test at the Wabun Bridge — Gage Spreading

As a result of the evaluation conducted at FAST, gage spreading and gage stiffness of the fastening systems zones were measured using 2 kips and 6 kips of gage spreading load applied to the railhead. Figure 4 shows the LTLF setup to apply the gage spreading forces to the head of the rails and the digital gages to measure the resulting railhead and rail base displacement. In this configuration, where the displacement gages were set up to measure the gage-side surfaces of the rail instead of the field-side surfaces (as typical), it was possible for test personnel to work within the track gage for added safety.

Figure 5 shows the gage spreading; i.e., the sum of the lateral displacement measured at the rail base and railhead of both rails resulting from the 6-kip applied load.

The results indicate negligible gage spreading strength differences (degradation) between the 2013 and the 2014 tests. Test zones 1a (Pandrol 16-inch cast plates at the west approach), 1b (Pandrol 16-inch cast plates on the bridge), and 3b (Pandrol 18-inch Victor at the east approach) performed similarly.

A comparison between test zones 1b and 3a (Pandrol 18-inch Victor on the bridge), however, indicates that the track gage (measured at the railhead) in zone 3a widened about 2.4 times more than in zone 1b under the same load. The same comparison of the rail base measurements indicates 3 times more widening in zone 3a than in 1b.

Both of these zones are on the bridge, both are fitted with rubber under-tie pads and both use e-clips. The differences between these two zones, Table 2, include type and number of plate-to-tie hold-down hardware, rail clip location, and the size of the tie plates.

Figure 4. LTLF applying Gage Spreading Forces to the Railhead

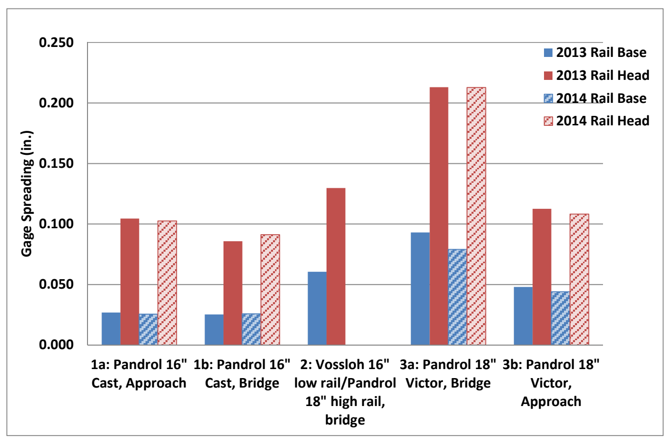

Figure 5. Gage Spreading

The test results indicate that the highest difference in low rail versus high railhead displacement was measured in zone 3a, where the high rail was 2.4 times higher than the low rail.

The Vossloh fastening system on the high rail of test zone 2 had been replaced with the Pandrol 18-inch Victor system when the gage strength test was conducted in 2013. The low rail was still fitted with the Vossloh system. Test zone 2, therefore, became a hybrid and an opportunity to evaluate the performance of the 2 systems in the different curve environments.

The railhead displacement measured on the high rail of test zone 2 (on the bridge), fitted with the Pandrol 18-inch Victor plate system, was 4.6 times more than that measured on the low rail, fitted with the Vossloh 16-inch plate system.

LTLF Static Gage Strength Test at the Wabun Bridge — Gage Stiffness

The gage spreading values reported thus far are a measure of the total lateral displacement of the system; i.e., lateral translation of the plate on the tie, lateral translation of the rail on the plate, and rail rotation of both rails as a function of the 6-kip gage spreading load, all relative to the tie.

Figure 6 shows rail lateral stiffness. This is a calculated value where it is assumed the first 2 kips of the applied load removes the majority of the slack in the system. The rail lateral stiffness is defined as: Δ gage spreading load/Δ lateral displacement, where Δ gage spreading load = 4 kips, (6 kips maximum load minus 2 kips initial load).

The results shown in Figure 6 indicate significant difference in stiffness between the high rail (Pandrol 18-inch Victor plate system) and the low rail (Vossloh 16-inch plate system) in test zone 2, where the low rail is 3.5 stiffer than the high rail. The most current (2014) results indicate almost twice higher stiffness in zone 1b than in zone 3a for both the high and low rails.

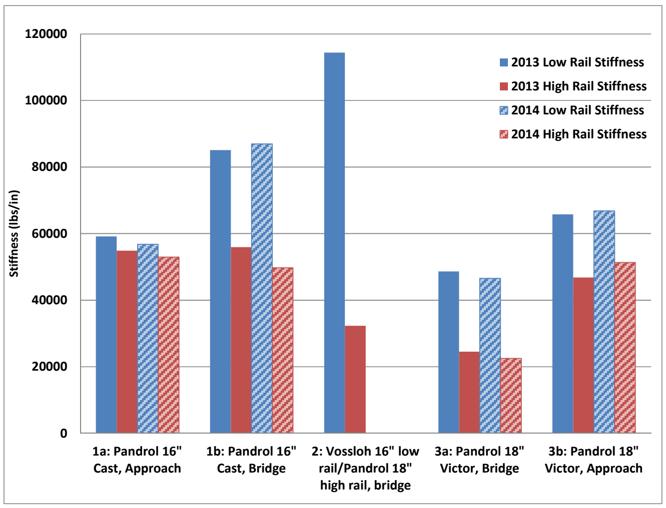

Figure 6. Rail Lateral Stiffness

FRA's GRMS Dynamic Gage Strength Test at the Wabun Bridge — Gage Spreading

The FRA's DOTX-218 Deployable Gage Restraint Measurement System (GRMS) applies nominal 14-kip lateral load and 21-kip vertical load (0.67 L/V) using a split axle and measures gage as it travels along the track. Figure 7 shows the 95th percentile gage widening ratio (GWR), a calculated value based on the change in gage and the applied gage spreading load. The results indicate the highest GWR is in test zone 3a. The similarity in the relative gage strength of the different test zones as measured with the LTLF (Figure 5) and with the GRMS, also known as the T-18 test car (Figure 7), is not entirely surprising given that both test methods apply the gage spreading load on the railhead.

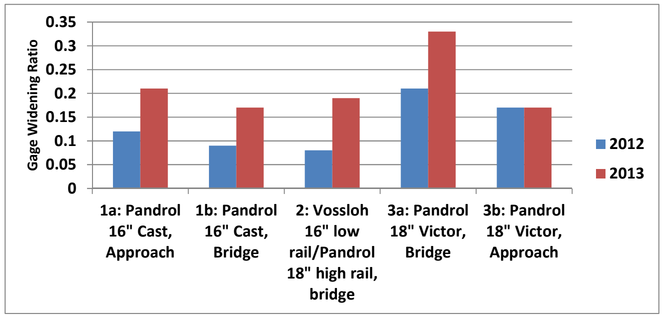

Figure 7. Gage Widening Ratio: FRA T-18 Test Car

GAGE DEGRADATION

Static gage measurements were taken with a standard track gage (Figure 8). The Pandrol 16-inch cast plate zone on the bridge (1b) degraded more initially than the Pandrol 18-inch Victor plate zone on the bridge (3a). However, from the second to third measurement, the higher degradation rate for System 1 was not observed and in fact the trend reversed. The last static track gage measured in all the test zones was between 56.75 and 57.00 inches.

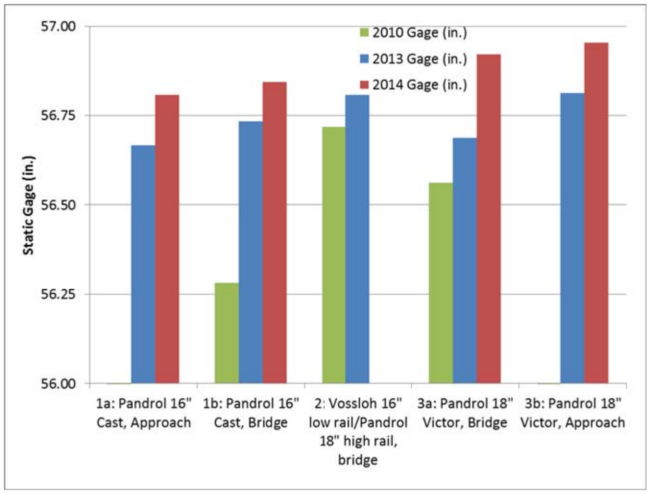

Figure 8. Gage Degradation

MAINTENANCE

In July 2011, NS reported that 17 Vossloh rail clip bolts broke on the high side of test zone 2 while replacing a rail flaw; some broke during installation. In September 2014, NS reported that rail clip bolts broke on the low side in the process of replacing worn rail. As a result, test zone 2 was removed. No broken rail clip bolts have been reported at FAST.

One Pandrol 16-inch cast plate broke along the rail base shoulder on the field side; a similar failure mode has occurred at FAST.

ACKNOWLEDGEMENTS

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