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Evaluation of the Effects of Switch Lateral Stiffness on Heavy Axle Load Performance

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Summary

Transportation Technology Center, Inc. (TTCI) evaluated the effects of removing selected lateral-stiffness components (stock rail braces) on the lateral stiffness of a mainline switch and thereby on turnout performance. The testing confirmed previous analytical studies that maximum lateral forces can be reduced by optimizing lateral stiffness in the turnout. This should lead to longer switch component lives and less alignment maintenance.¹

The comparison was made using the Canadian Pacific Railway standard stock rail brace pattern turnout with stock rail braces on every tie in the switch area and the same turnout with a more typical stock rail brace pattern of every other tie. Following are the findings:

- Static Testing (TTCI's Track Loading Vehicle applied 33,000-pound vertical wheel and 20,000-pound gage-spreading load, a 0.6 wheel lateral to vertical (L/V) ratio.)
 - Both stock rail brace configurations tested had the characteristic gage and lateral stiffness signature of a split switch, where the point of switch is tighter and stronger than the weaker switch heel.
 - Although the loaded gage measured along the switch was mostly tighter when all the braces are in place, the difference was very small, less than 0.15 inch when the switch was lined for the main.
 - The same general loaded-gage characteristics along the mainline route, tighter point of switch and wider switch heel, are also present along the diverging route of the turnout.
 - The weaker area is 20 to 30 feet past the point of switch and beyond where the switch point head contacts the stock rail. This portion of the turnout depends on floating braces between the switch point and the stock rail for its gage strength. Beyond that, rail clips provide the rail restraint. The fit of these floating braces may need to be addressed in order to increase the gage strength in this area of the turnout.
 - There was little change in gage strength (loaded change in gage) near the point of switch when every other stock rail brace was removed.
- Dynamic Testing (Lateral rail movement was measured along the switch using displacement transducers under 39-ton axle load traffic at 40 mph.)
 - In general, the stock rails are moving inward and the switch points are moving outward.
 - Inward displacement measured at the stock railheads was very small, approximately 0.02 inch.
 - The displacements measured near the top of the curved point at four locations along the point during diverging moves indicate the same basic lateral stiffness/strength signature of a split switch, where the heel area is weaker (higher displacement) than the rest of the switch point.
- Effects of Lateral Stiffness on Wheel and Rail Forces (wheel/rail forces were measured along the switch using strain gaged wheelsets under 39-ton axle load traffic at 40 mph.)
 - The instrumented wheelset tests showed the impact wheel lateral forces and L/V ratios on the switch with fewer rail braces were decreased by 20 to 30 percent because of the track lateral flexibility introduced.



INTRODUCTION

Turnouts allow trains to move from one track to another. Due to their function and unique structure, turnouts are locations where high dynamic forces may be generated. These forces come from a variety of sources. The most obvious are from the frog flangeways: gaps in the running rails that can cause impact loads. The switch may have an alignment discontinuity on the diverging route. A nontangential switch, typically used in North American freight operations, has an entry angle that can generate large lateral forces over a relatively short distance.

Much effort has been expended by the industry to eliminate or mitigate the impact causing features of turnouts, such as better alignment design and improved performance frogs.²⁻⁴ This has resulted in significantly longer service lives for turnouts under heavy axle loads.⁵ However, large dynamic loads are still measured in these improved-performance turnouts.

In addition to these sources of dynamic load, there are the more subtle ones related to changes in track structure. Longer crossties, as the two tracks in the turnout diverge, make the turnout vertically stiffer than the surrounding track. In the same way, multiple rails and tie plates that span multiple ties can change the stiffness and damping characteristics of the turnout. Additional bracing, commonly called stock rail braces, can also make the switch end of the turnout stiffer than open track in the lateral plane.

Test Turnouts

A series of experiments are being conducted using a No. 20 turnout on the High Tonnage Loop at the Facility for Accelerated Service Testing. The turnout has an AREMA-style secant alignment and a fixed-point frog. The turnout was donated by Canadian Pacific (CP) Railway and is representative of mainline turnouts being installed in service across North America.

The lateral stiffness experiment described here involves varying the number and spacing of stock rail braces in the switch. Two cases were evaluated: (1) the CP standard configuration of braces on every tie in the switch and (2) the configuration, used by some other railways, of a brace on every other tie.

In-Track Tests

The following tests were conducted:

- Loaded gage and change in gage were measured along the turnout as TTCI's Track Loading Vehicle (TLV) applied static 33,000-pound vertical and 20,000-pound gage-spreading loads, producing a 0.6 L/V ratio.
- Dynamic lateral rail movement was measured along the switch using displacement transducers under 39-ton axle load traffic at 40 mph.
- Dynamic lateral wheel forces were measured along the turnout using instrumented wheelsets (IWS) under the same operating conditions.

FINDINGS

Static Testing

Figures 1 and 3 (mainline routes) and 2 and 4 (diverging routes) illustrate the characteristic gage and lateral stiffness signature of a split switch as derived from static TLV-loaded absolute gage and change in gage measured along the turnout, where the point of switch is tighter and stronger than the wider and weaker switch heel.

Figure 1, a comparison of the CP standard stock rail brace pattern turnout (stock rail braces on every tie in the switch area, round blue data points) and the same turnout with a typical stock rail brace pattern (every other brace removed, diamond green data points) after 58 MGT, indicates that although the loaded gage along the switch was mostly tighter when all the braces are in place, the difference was small, less than 0.15 inch when the switch was lined for the main.

Some degradation in the switch occurred as a result of 58 MGT of HAL traffic as indicated by the upward (increasing) shift in the loaded gage plotted in Figure 1. Although the largest increase in loaded gage was 0.2 inch, the majority of the locations measured were 0.1 inch or less.

Figure 2 indicates that the same general loaded gage characteristics along the mainline route, tighter point of switch and wider switch heel, are also present along the diverging route of the turnout. Two additional similarities shared by the main line and the diverging routes are the increased absolute gage (degradation) after 58 MGT and the loaded gage measured with all braces in place versus every other brace removed.

The data plotted in Figures 3 and 4 is derived from the same TLV static gage-spreading test and is presented in terms of delta gage. Where Figures 1 and 2 are plots of the absolute track gage, Figure 3 illustrates the change (increase) in gage as a function of the applied load along the mainline route, an indication of track gage strength.

The plot in Figure 3 indicates that under the 0.6 L/V ratio, the track widened about 0.05 inch along the open track approaching the turnout and within the switch portion of the turnout. The increase in lateral rail deflection at about 30 feet past the point of switch is beyond where the switch point head contacts the stock rail. This portion of the turnout depends on floating braces between the switch point and the stock rail for its gage strength. Beyond that, rail clips provide the rail restraint. The fit of these floating braces may need to be addressed to increase the gage strength in this area of the turnout.

Figure 3 also indicates little change in gage strength near the point of switch when every other stock rail brace was removed (blue diamond data points).

Figure 4 is a plot of gage strength along the diverging route and shows (a) minimal difference in having stock rail braces on every tie and (b) increased rail lateral displacement at about 30 feet past the point of switch. In this case, the displacement at 30 feet is almost 0.1 inch greater than was measured over the mainline route. This is due to the turnout throw mechanism

not fully moving the entire length of switch point. The order in which the measurements were taken, where the mainline route was measured first, and then the switch was lined for the diverging route for those measurements without train traffic to seat the point to the stock rail, may have contributed to the increased lateral displacement.

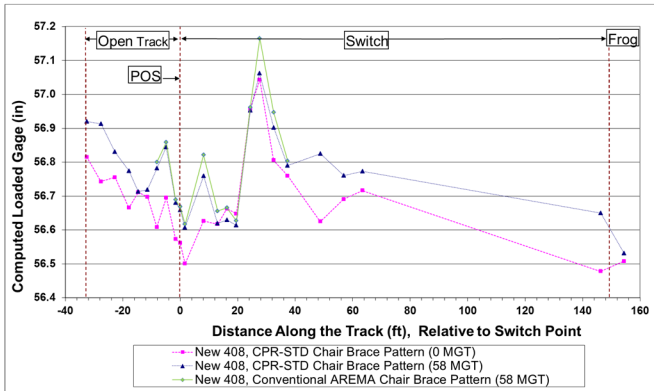


Figure 1. Loaded Gage along the Turnout Lined for Mainline Traffic — CP Standard Every Tie Stock Rail Brace Pattern, Newly Installed and After 58 MGT Compared to the Every Other Stock Rail Brace Pattern

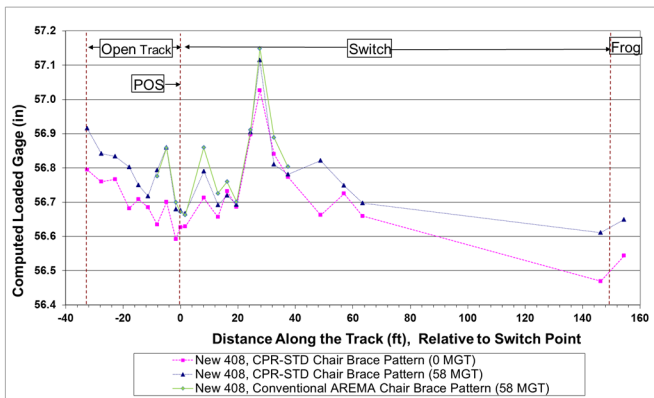


Figure 2. Loaded Gage along the Turnout Lined for Diverging Route Traffic

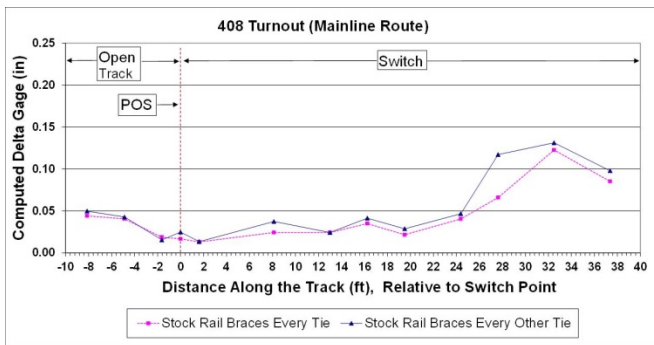


Figure 3. Gage Strength along the Mainline Route of the Turnout, where Lower Delta Gage indicates Stronger Track

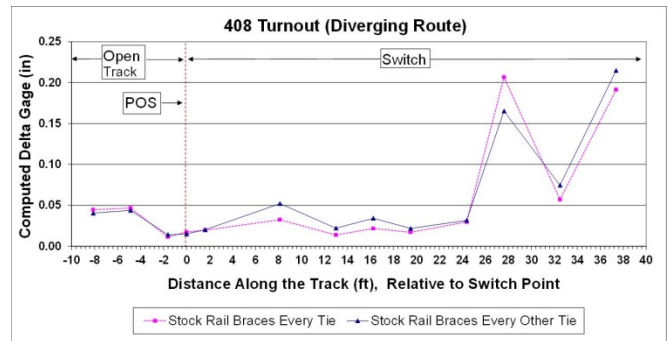


Figure 4. Gage Strength along the Diverging Route — Increased Delta Gage at About 30 Feet Due To the Switch Mechanism Not Fully Lining the Back of the Point

Dynamic Testing

Bending beams are transducers designed to measure dynamic lateral displacement at the railhead and base. Bending beams fabricated by TTCI’s instrumentation group were installed along the switch area of the turnout to measure the displacement of the switch points and stock rails under HAL traffic (Figure 5).

At every location measured on the stock rails, the largest deflections were inward; i.e., gage tightening. At every location measured on the switch point, the largest deflections were gage widening.



Figure 5. Bending Beams (Displacement Transducers) in Place to Measure Dynamic Lateral Railhead and Base Displacement under Traffic

The schematic-plot presented in Figure 6 illustrates the direction (relative to the track gage) and magnitude of displacement (95th percentile, three trains) measured using bending beams on the head of the curved stock rail, the curved point, and the straight stock rail as the HAL train ran from the bypass to the main line in trailing point direction at 40 mph.

The two locations measured on each of the two stock rails indicate inward head displacement under 0.02 inch. The displacements measured near the top of the curved point at four locations along the point indicate the same basic lateral stiffness and strength signature of a split switch, where the heel area has higher displacement (0.13 inch) than the rest of the switch point.

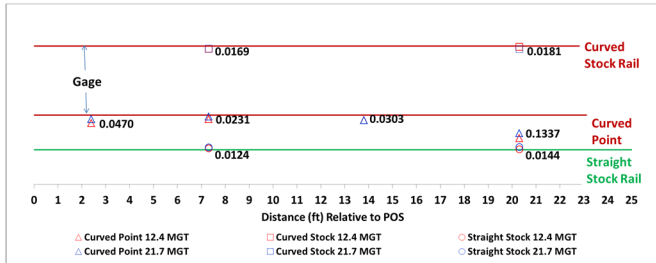


Figure 6. Bending Beam Data: Dynamic Head Displacement (Direction and Magnitude) of the Three Rails Involved in Trailing Point Traffic over the Diverging Route

Figure 7 shows the inward head displacement measured on the curved stock rail during diverging, trailing point, and facing point traffic after half of the stock rail braces were removed was less than 0.02 inch.

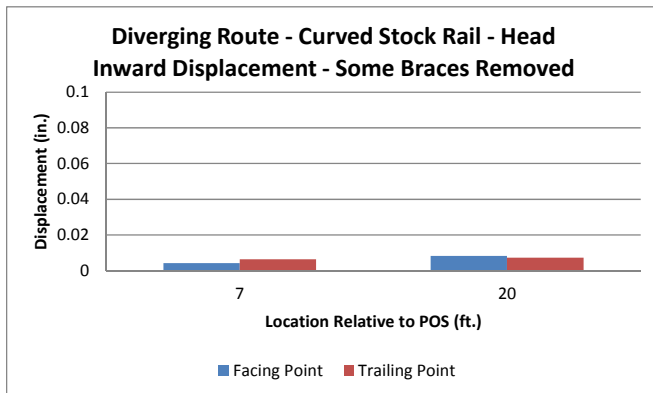


Figure 7. Bending Beam Data: Dynamic Curved Stock Rail Head Displacement, Every Other Stock Rail Brace Removed, Facing and Trailing Point Traffic

Effects of Lateral Stiffness on Wheel and Rail Forces

Figure 8 shows the comparison of the measured wheel lateral forces and L/V ratios on the CP switch with all braces (red lines) and every other brace (blue lines) installed. Note that the short duration impact peak seen for each wheel as it contacts the diverging switch point for the every tie brace case (shown in red) is not present for the every other tie brace case (shown in blue). This area is circled in Figure 8.

The IWS test data showed the impact wheel lateral forces and L/V ratios on the switch with fewer rail braces were decreased by 20 to 30 percent on all wheels because of the introduction of track lateral flexibility.

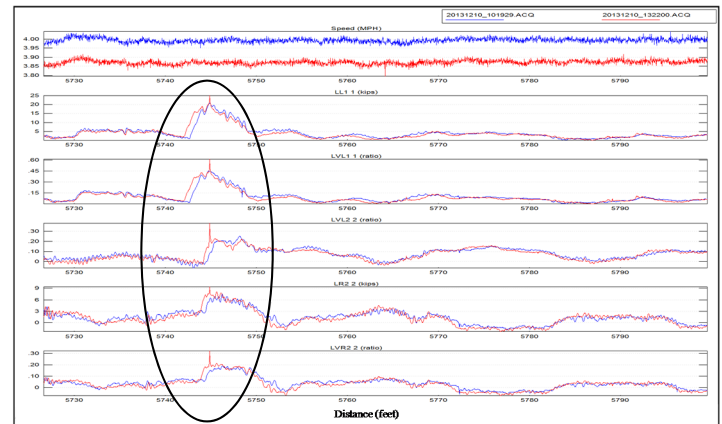


Figure 8. Time Histories of Measured Lateral Force and L/V Ratios for the No. 20 Turnout at FAST with Stock Rail Braces Every Tie and Every Other Tie

Other experiments being conducted on this turnout include:

- Ongoing alignment test — a time series comparison of a pre-steered switch² and an AREMA style secant alignment switch. Results are expected to be published in 2015.
- Foundation (vertical) stiffness test — evaluation of the effects of uniform (designed vertical stiffness) and non-uniform (current construction) vertical stiffness in the turnout. This was accomplished by installing under tie pads to the turnout.⁶

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