TECHNOLOGY DIGEST

TD-14-022
©NOVEMBER 2014

TIMELY TECHNOLOGY TRANSFER

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# Evaluation of a Foundation Design for Turnouts under Heavy Axle Load Traffic

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## Summary

In a multiphase program, Transportation Technology Center, Inc. is evaluating the performance of a set of polyurethane under-tie pads intended to minimize vertical stiffness changes in a turnout and reduce the effects of impact loads. The pads provided performance benefits in testing under 39-ton axle loads on a mainline timber turnout. These benefits included:

- The variation in the vertical stiffness over the frog panel was reduced by approximately 70 percent using the under-tie pads based on the measured range. The stiffness throughout the frog panel of the previous turnout without pads varied from 500,000 lb/in maximum, 231,000 lb/in minimum as compared to the frog panel with under-tie pads, which varied from 267,000 lb/in maximum, 195,000 lb/in minimum.
- A comparison of the frog panel section of the turnout with under-tie pads and the switch panel section without pads indicates less settlement variation in the frog panel between 20 and 50 percent based on standard deviation.
- During Phase I, the portion of the turnout with under-tie pads; i.e., the entire turnout, except the switch panel, settled about 30 percent less than the switch panel without pads throughout the period of performance.
- The vertical dynamic responses in open track and at the unpadded switch panel are generally bigger than other padded panels. The effect of padded ties on switch dynamic response needs to be further evaluated in Phase II.
- The relative difference of the variation in dynamic response and the 95th percentile dynamic load measured at the critical interface between the long turnout ties and the standard ties was reduced when the long turnout ties were fitted with under-tie pads. At this track structure transition, the under-tie pads provided the smoothing effect for which they were designed.
- Phase II of this test is currently underway. Phase II will provide a direct comparison of the performance of the entire turnout fitted with under-tie pads and the previous turnout with no under-tie pads. It will also provide a comparison of differential stiffness and settlement of the two switch panels tested during both phases, looking at both the entire switch panel and the interface of the switch panel with the rest of the turnout.

The test turnouts measured in this experiment were mainline No. 20 turnouts on the high tonnage loop at the Facility for Accelerated Service Testing, Pueblo, Colorado. The turnouts have AREMA-style, nontangential alignments, railbound manganese frogs, 136RE welded rail and timber crossties.

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## INTRODUCTION

Turnouts allow trains to move from one track to another. Due to their function and unique structure, turnouts are located where high dynamic forces may be generated. These forces come from a variety of sources. The most obvious are from the frog flangeways. These are 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.[1-3] This has resulted in significantly longer service lives for turnouts under heavy axle loads (HAL).[4] However, relatively high 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 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.

### Test Turnouts

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

The foundation experiment described here involves use of under-tie pads intended to create uniform vertical stiffness throughout the turnout and reduce the effects of impact loads. Two different stiffness pads were used in the turnout, with the softer pad being used under the frog. Due to the sequencing of additional experiments, the turnout was installed with the under-tie pads on all ties except for the switch panel (the first ~40 feet of the turnout). Performance comparisons were made between the padded and unpadded portions of the turnout. Comparisons were also made between the test turnout and previous turnouts at this location.

### Test Turnout Installation

Canadian Pacific Railway donated a complete No. 20 turnout fitted with donated Getzner, USA, polyurethane under-tie pads plus an additional switch panel without the pads. The existing turnout and approaching track (about 225 feet) was removed and the Phase I test turnout was installed. The 136RE rail in the turnout panels were welded using electric flash and thermite welds. Phase I consisted of two closure panels, the frog panel, and an additional panel beyond the frog, all with under-tie pads. The switch panel without the under-tie pads was installed during Phase I and new granite ballast was installed throughout the turnout. The focus of Phase I was to quantify the performance of the switch panel without pads as compared to the rest of the padded turnout and to gather data for direct comparison with Phase II, where the padded switch panel is being tested.

## RESULTS

### Vertical Stiffness

The vertical track stiffness over the mainline route of the turnout was determined using TTCI's Track Loading Vehicle (TLV). The TLV applied 10,000- and 40,000-pound static vertical loads at each of 46 locations along the turnout. The change in vertical deflection measured between the two vertical loadings was used to calculate stiffness in terms of pound-inch.

Six turnout approach measurements were taken over 21 feet of open track ahead of the switch point where unpadded ties were installed. Fourteen measurements were taken over the 57-foot switch panel: 12 measurements over closure panels 1 and 2, 8 measurements over the 42-foot frog panel, and 6 measurements over the 37-foot panel past the frog panel.

Figure 1 shows the results of vertical stiffness tests conducted on the two No. 20 turnouts on the HTL at FAST and illustrates abrupt changes throughout. Also evident are the hard points that can increase dynamic loads and cause differential settlement. The stiffest part of the 407 turnout was measured near the point of switch where hollow steel ties designed for concrete turnouts were installed.

The turnout that was in track before the test turnout was installed for Phase I is the primary basecase for this experiment. Figure 1 shows that this turnout also exhibits numerous changes in stiffness throughout, with the highest measured at the frog.

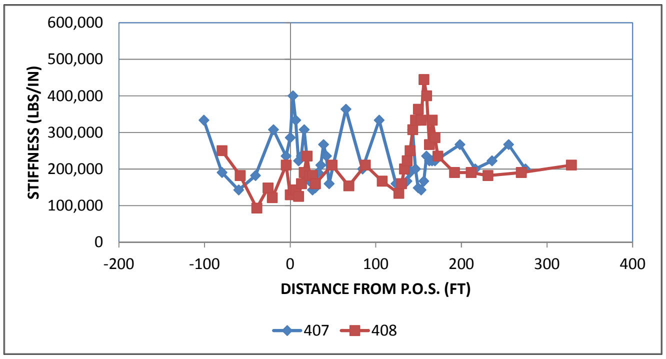

**Figure 1. Two No. 20 Turnouts on the HTL at FAST without Under-Tie Pads Exhibiting Changes in Vertical Stiffness and Stiff Areas of the Switch Points and Frog**

Figure 2 is an overlay of the vertical stiffness measured on the basecase turnout (no pads) and that measured on the Phase I test turnout at the same location.

The Phase I test turnout fitted with under-tie pads from closure panels 1 through 5 exhibits reduced stiffness variation and a significant reduction in maximum stiffness in the frog panel.

The variation in the vertical stiffness over the frog panel was reduced by approximately 70 percent using the under-tie pads based on the measured range. The stiffness throughout the frog panel of the previous turnout without pads varied approximately 269,000 lb/in (500,000 lb/in maximum and 231,000 lb/in minimum) as compared to the frog panel with under-tie pads, which varied about 72,000 lb/in (267,000 lb/in maximum, 195,000 lb/in minimum).

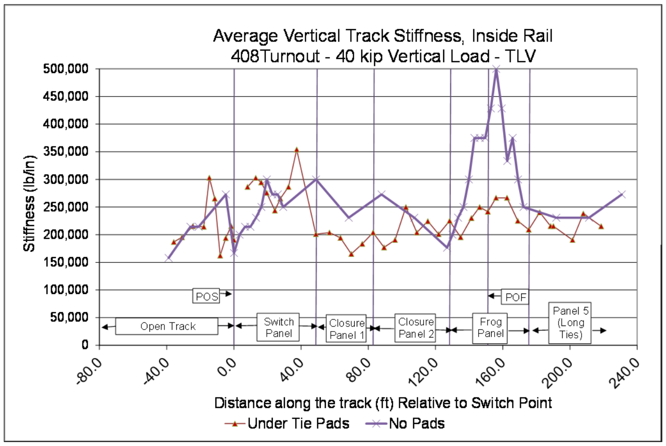

**Figure 2. Reduced Vertical Stiffness and Variation in Stiffness in Phase I Test Turnout (pads from closure panel 1 to end of turnout) Compared to Baseline Turnout (no pads)**

Figure 3 illustrates the vertical stiffness of the Phase I turnout when newly installed and after 58 MGT. The data indicates that the significant reduction in stiffness measured at the frog and the reduction in variability throughout the portion of the turnout with under-tie pads is sustainable after 58 MGT.

Figure 3 indicates that the switch panel of the Phase I test configuration and the open track approaching the turnout, both without under-tie pads, continue to exhibit higher stiffness and variation after 58 MGT.

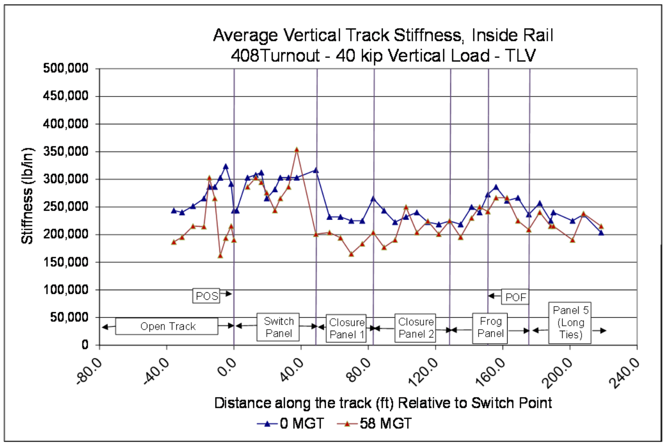

**Figure 3. Reduction in Vertical Stiffness and Variation in Under-Tie Pad Section of the Turnout Sustainable after 58 MGT of HAL Traffic**

## Vertical Settlement

Figure 4 illustrates the amount of vertical settlement and the variation in settlement along the entire turnout from top of rail (TOR) elevation measurements during 82 MGT of HAL traffic. A reduction in differential settlement; i.e., improvement in track surface uniformity, is one of the performance goals of under-tie pads. A comparison of the frog panel section of the turnout with under-tie pads and the switch panel section without pads indicates less settlement variation in the frog panel between 20 and 50 percent based on standard deviation.

The direct comparison between the switch panels without under-tie pads and with under-tie pads will be made when Phase II is completed.

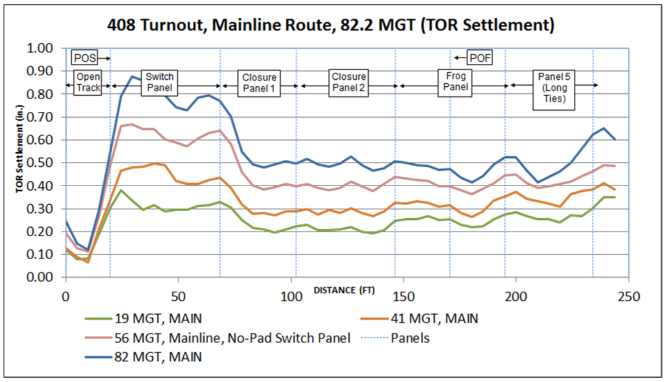

**Figure 4. Top of Rail Elevation Measurements along the Turnout Show Differential Settlement between Section with and without Under-Tie Pads as well as Variations within Each Section**

Figure 5 indicates that the portion of the turnout with under-tie pads (closure panels 1 and 2, frog panel, and panel 5) settled about 30 percent less than the switch panel without pads throughout the period of performance.

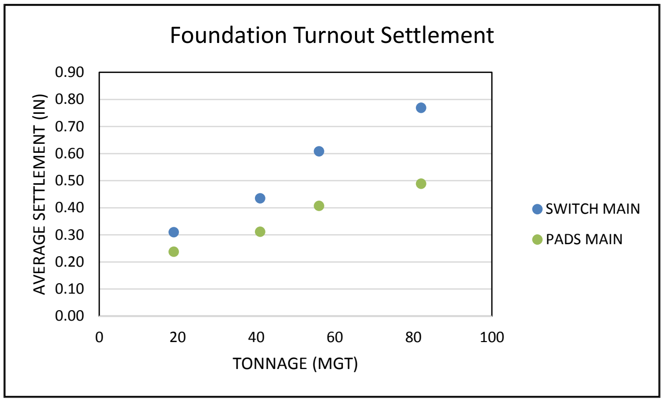

**Figure 5. Thirty Percent more Vertical Settlement in Switch Panel without Under-Tie Pads than in Rest of Turnout where Ties were Fitted with Pads**

## Vertical Forces

Figure 6 shows the measured wheel vertical and lateral forces of the Phase I turnout when newly installed. The forces were measured when the instrumented wheelset car was running counterclockwise on a facing point diverging move through the turnout at 40 mph.

Figure 6 shows the standard deviation of the measured vertical dynamic axle load in the turnout area — the bigger the standard deviation, the bigger the vertical dynamic response variation.

The vertical dynamic response in the adjacent open track and unpadded switch panel are generally bigger than other padded panels. In Phase II testing, the effects of padded ties on switch dynamic response will be directly assessed.

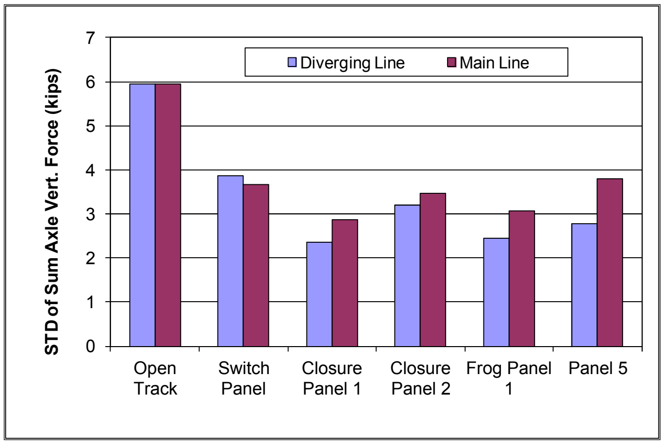

**Figure 6. Standard Deviation of Vertical Axle Dynamic Forces**

Figures 7 and 8 indicate that for the baseline turnout, where no pads were used, the standard deviation and the 95th percentile dynamic load, respectively, measured over the stiffer long turnout ties was greater than those measured over the standard ties. Dynamic vertical load variability was approximately 46 percent higher over the long turnout ties than over the standard ties. The 95th percentile dynamic load was approximately 7 percent higher over the long turnout ties than over the standard.

By comparison, when the pads were installed under the long ties of the test turnout but not in the standard ties beyond, both the variability and the 95th percentile dynamic load were reduced at this critical interface. Further, the differences in vehicle performance between turnout (Long Ties) and open track (Standard Ties) have been reduced by using undertie pads at this transition.

Other experiments being conducted on this turnout include:

- Ongoing alignment test – a time series comparison of a pre-steered switch[1] and an AREMA style secant alignment switch. Results are expected to be published in 2015.
- Switch lateral stiffness test – Comparison of switch performance under different switch lateral stiffness. This was accomplished by removing stock rail braces from some locations.[5]

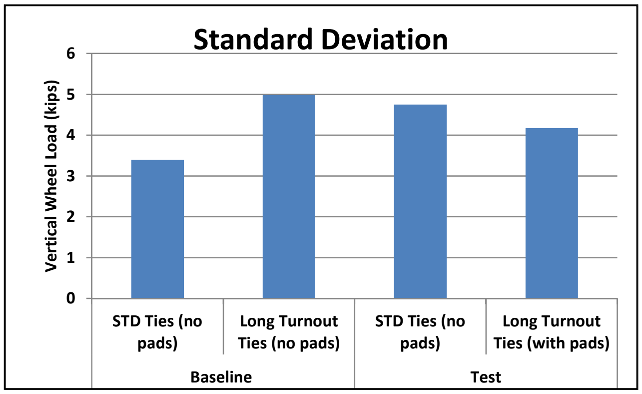

**Figure 7. Standard Deviation of Vertical Dynamic Forces at the Interface between the Long Turnout Ties and the Standard Ties approaching the Turnout in the Trailing Point Direction**

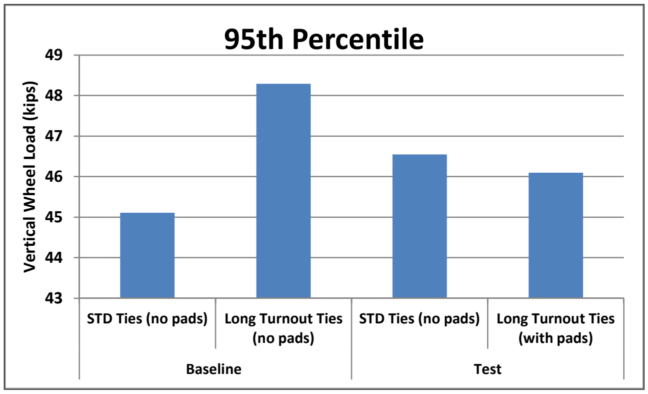

**Figure 8. 95th Percentile of Vertical Dynamic Forces at the Interface between the Long Turnout Ties and the Standard Ties approaching the Turnout in the Trailing Point Direction**

## ACKNOWLEDGEMENTS

TTCI wishes to thank Canadian Pacific Railway for donation of the No. 20 turnout and Getzner, USA, Inc. for donation of the polyurethane under-tie pads for this project.

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