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Half-Frame Concrete Tie Performance under HAL Traffic: Selected Applications

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Summary

Preliminary testing of the half-frame concrete tie (HFT) at the Facility of Accelerated Service Testing (FAST) has shown a significant reduction in ballast degradation, reduced curved track ballast migration, and increased lateral resistance. HFTs continue to accumulate tonnage on the High Tonnage Loop at FAST and their performance continues to be monitored.

The HFTs at FAST have accumulated 721 million gross tons (MGT) as of September 1, 2014. Due to these observed performance enhancements, three revenue service applications on the Union Pacific Railroad were selected to test the HFT. At the western mega site near Ogallala, Nebraska, HFTs are being tested in the approaches of two ballasted deck bridges as well as underneath two insulated joints (IJ). Near Pendleton, Oregon, 207 HFTs have also been installed on a high degree curve. The HFTs being tested at all sites are fitted with an under-tie pad. To date, no failures have been observed for the HFTs at FAST or in revenue service.

The HFTs within the bridge approaches at the western mega site have accumulated between 719 and 725 MGT as of September 1, 2014. Dynamic testing has been completed to compare the performance of a HFT bridge approach to a conventional concrete tie approach under similar loading conditions (i.e., 286-kip gross rail load cars at 40–50 MPH). Significant differences in tie acceleration, tie deflection variability, and tie bending strain were observed under heavy axle load trains between the two bridge approaches, with HFTs outperforming conventional concrete ties in all measures. HFTs are also being tested under two IJs at the western mega site and the performance of the ties and the IJs they support are being documented. These ties have accumulated 690 MGT as of September 1, 2014.

Performance of the HFTs installed on the 7-degree curve near Pendleton is being compared with conventional concrete tie performance using track geometry, vehicle-track interaction, and lateral curve movement data. These ties have accumulated about 90 MGT as of September 1, 2014.

To augment initial data on ballast degradation beneath the HFTs at FAST, a more comprehensive method was used to better characterize the degradation of the ballast beneath the HFTs and a zone of conventional concrete ties. Cross-trenches were dug and ballast images were collected and analyzed to characterize the ballast degradation. Estimates from this imaging suggest that 52 percent of ballast life is remaining under the HFTs compared to 20 percent under the conventional ties after 645 MGT.

Due to their advantages over conventional concrete ties (larger footprint, larger rail seat, and increased lateral resistance), the HFTs appear to lend themselves to applications in bridge approaches, IJ support, and high degree curvature track. The preliminary results of these long-term tests indicate the HFTs are performing well in these selected applications. The HFTs for these tests were installed with a nominal 24-inch spacing.

This investigation is being undertaken by the Transportation Technology Center, Inc., under the co-sponsorship of the Association of American Railroads and Federal Railroad Administration.



INTRODUCTION

The preliminary experimental results of concrete HFTs at FAST during 265 MGT of heavy axle load (HAL) traffic, indicated improved performance compared to conventional concrete ties, including reduced ballast degradation, minimal ballast migration on superelevated curved track, and significantly higher lateral resistance.¹

Given these results, Transportation Technology Center, Inc. proposed the installation of HFTs at two mainline revenue service locations on the Union Pacific Railroad to evaluate their long-term performance: (1) the HAL coal route at the western mega site near Ogallala, Nebraska, and (2) on a high degree curve between Pendleton and La Grande, Oregon. Testing has also continued on the High Tonnage Loop (HTL) to assess ballast degradation beneath the HFTs as additional tonnage is further accumulated.

All HFTs being tested at FAST and in revenue service are fitted with a Getzner elastomeric under-tie pad and Vossloh elastic fastening system.

HFTs at Bridge Approaches

Based on their larger footprint and under-tie pads, the HFTs have potential to reduce impact loads to the ballast and minimize surface deviations typical of bridge transition zones, especially under HAL traffic. To this end, the HFTs were installed on three bridge approaches at the western mega site.

Two ballasted deck bridges, located on tangent track on the loaded HAL coal route, were selected for this study. Fifteen ties were installed during summer 2011 at the east and west approach of the bridge near Oshkosh, Nebraska (the former of which is shown in Figure 1) and at the west approach of the bridge at near Paxton, Nebraska. The test ties were installed using an excavator with a grapple attachment (Figure 2) and a standard production switch tamper with split work heads.

The HFTs at these bridge approaches have been in service for approximately 719–725 MGT as of September 1, 2014. No major maintenance has been conducted on these ties aside from regularly scheduled surfacing in the area, and no tie cracking or fastener issues have been observed to date. Due to the predominantly one-directional HAL traffic at the western mega site (i.e., eastbound 286-kip gross rail loads at 40–50 MPH), the east and west approaches may behave differently as traffic approaches these bridges traveling west to east.

To assess the performance of the HFTs for bridge approach applications, dynamic data, including rail and tie accelerations, tie bending strain, and tie deflection, were collected for bridge approaches containing the HFTs and conventional concrete ties under HAL trains. Data was collected on the east approach of both bridges to compare HFT performance against conventional concrete ties. It was thought that that the east approaches would have a more severe loading environment. It should be noted that dynamic measurements at the HFT approaches were conducted approximately one year (~240 MGT) after initial tests at the conventional concrete tie approach. Figure 3 shows the instrumentation setup.

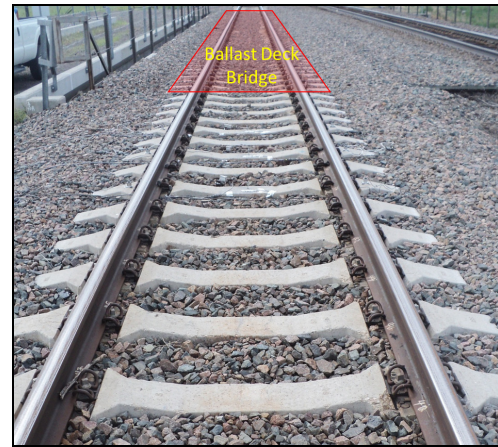


Figure 1. HFTs on the East Approach near Oshkosh, NE



Figure 2. Installation of the HFTs on the Bridge Approach

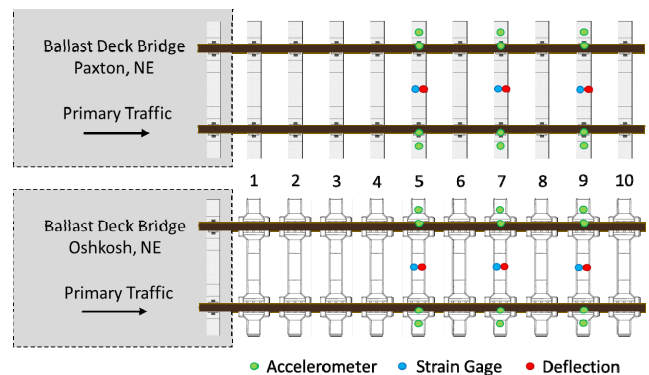


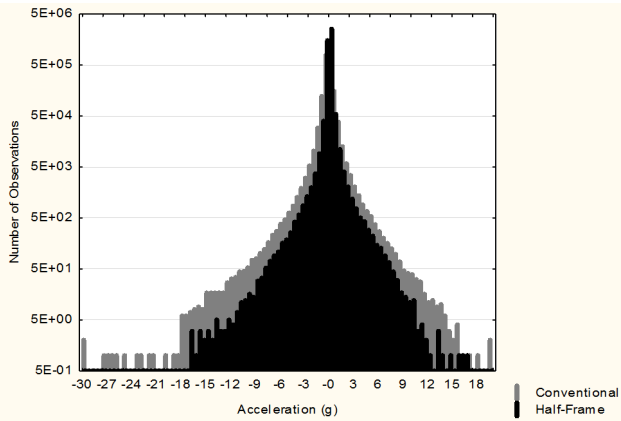
Figure 3. Instrumentation on the Cross-ties in the Approaches

Figure 4 shows the frequency distribution for all tie acceleration channels collected under five HAL unit coal trains at each approach. Results presented in the figure show a significant reduction in vibration on the HFTs over conventional concrete ties in a similar dynamic environment.

Furthermore, results from this testing show significantly lower tie peak bending strains as the summary statistics in Table 1 show.

Test results for the conventional ties show lower, but more variable, deflections under HAL wheel loads. The larger deflections observed for the HFTs are likely attributed to the

lower overall track modulus provided by HFT's under-tie pads. There is a significant reduction in deflection variability, suggesting more consistent deflection for the HFTs under HAL traffic than the conventional concrete ties, as Figure 5 shows.



*Significant difference (p < 0.005)

Figure 4. Frequency Distribution of Tie Accelerations

Table 1. Range of Peak Tie Bending Strains

		Peak Bending Strain (μϵ)						
		Mean	StDev	Min.	Q1	Median	Q3	Max.
Tie 5	Conventional	438.8	31.7	352.3	437.4	448.8	459.2	493.8
	Half-Frame	95.0	15.3	63.9	79.5	100.2	108.2	121.9
Tie 7	Conventional	453.0	34.0	372.1	445.2	464.7	477.7	504.3
	Half-Frame	142.0	10.8	114.4	133.9	140.5	150.2	174.1
Tie 9	Conventional	425.2	31.9	349.8	419.1	435.5	448.0	482.9
	Half-Frame	98.2	6.2	82.9	94.0	98.1	102.5	118.5

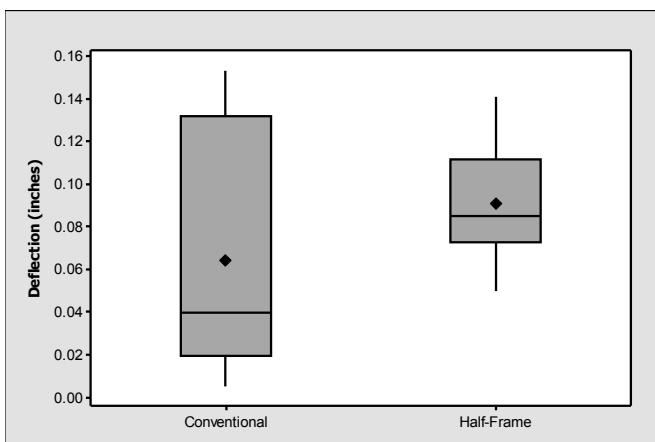


Figure 5. Box Plot of Tie Deflection for Three Representative HAL Train Passes over Each Approach

HFTs as Support for Insulated Joints

The increased footprint and larger rail seat of the HFT were also desirable characteristics for the support of impact loads such as those observed at IJs. To test performance in this area, 14 HFTs were installed on the western mega site in 2011 to support two IJs at a mainline control point. The joints were installed fully supported above the larger rail seat, as Figure 6 shows. These HFTs have accumulated 690 MGT as of

September 1, 2014, and have continued to perform well for this application. Planning is underway to install HFTs under additional IJ locations to further monitor the benefits of the HFTs for IJ support applications.



Figure 6. HFTs supporting a Pair of IJs at a Control Point

HFTs in High Degree Curvatures

Another revenue service HFT test zone has been installed on the La Grande subdivision of the Union Pacific Railroad near Pendleton. Due to the high lateral strength of the HFT seen at FAST, the HFTs were selected for installation in a high degree curve to reduce curve movement and maintain track geometry. Figure 7 shows the test zone where the 207 HFTs were installed in a 7.2-degree curve.



Figure 7. HFT Test Zone near Pendleton, OR

The installation of these ties was completed in the fall of 2012. The ties were installed in a similar manner as the bridge approaches on the western mega site. The zone has accumulated about 90 MGT through September 1, 2014. Moving forward, track geometry, vehicle-track interaction, and lateral curve shift data will be collected as tonnage is accumulated and a performance comparison will be made with an adjacent conventional concrete tie control zone.

Reduced Ballast Degradation Observed at FAST

The 190 HFTs installed at FAST comprise one zone of a five-zone test section of concrete ties in Section 3 of the HTL, a 5-degree curve. The ballast, which was placed in both the HFT and conventional concrete tie test zones at the time of installation, was a combination of new and screened track ballast of the same type and consistent with that used on Class I mainline track. As this test zone continues to accumulate tonnage (721 MGT as of September 1, 2014), testing will continue to assess performance of the HFTs. Ballast samples have been collected and analysis of sieve results has indicated reduced ballast degradation beneath the HFTs relative to the conventional concrete tie zone. However, due to the variability of ballast sampling (gradation can vary significantly along the tie and with depth below the tie) and small sample sizes, a more comprehensive method is required to better characterize the ballast degradation beneath the five tie zones.

To this end, lateral cross trenches were dug across the tie zones and images were collected of the trench sidewalls that corresponded to the ballast beneath the tie, as Figure 8 shows. FAST provides a better environment for this type of intrusive data collection as it is a more controlled test site compared to revenue service.

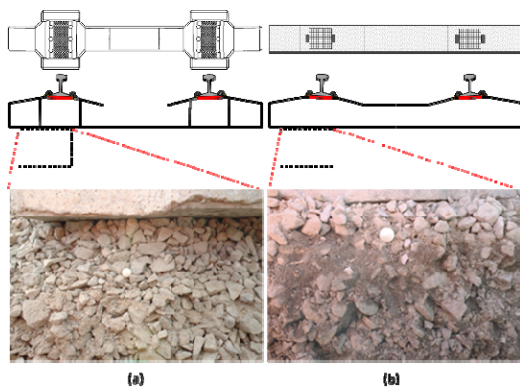


Figure 8. (a) Ballast Image 171 – Below the Inside Rail of HFT and (b) Ballast Image 150 – Below the Inside Rail of Conventional Concrete Tie

In collaboration with the University of Illinois at Urbana-Champaign, these images were processed using a segmentation analysis that allows individual ballast particles to be identified and their size relatively quantified.² From this technique, an image-based fouling index (IBFI) is calculated for each image. Based on the images collected for this analysis, an IBFI of 40 to 80 is assumed to characterize the range of realistic ballast conditions (from new ballast to ballast sufficiently degraded to warrant undercutting/cleaning). Figure 9 shows where the average IBFI beneath the HFTs and the conventional concrete ties falls on the spectrum of ballast condition after 645 MGT. Estimates from the images suggest that 52 percent compared to 20 percent of ballast life is remaining for the ballast beneath the HFTs and conventional concrete ties, respectively.

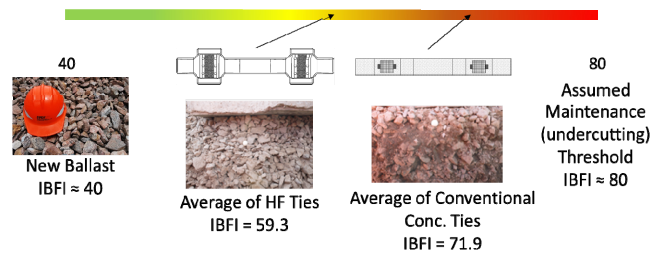


Figure 9. Average IBFI for the Half-Frame Tie and Conventional Concrete Tie Zones after 645 MGT

OTHER OBSERVATIONS

Some rail clips were retightened on the HFTs installed at the west approach of the bridge near Paxton soon after installation and the rail seat pads under those loose clips had shifted slightly. Clips were also adjusted at Pendleton after installation as over tightening was initially observed. All of the rail clips on the HFTs that support the IJs as well as the ones at the bridge approach near Oshkosh have remained tight. The majority of plastic caps installed to seal the unused rail clip bolt holes have disintegrated, presumably from environmental exposure. None of the HFTs or their fastening system components has failed and no track geometry (i.e., surfacing) spot-maintenance has been reported beyond regularly scheduled operations in the area. Visual indication of ballast abrasion and degradation on the revenue service installations is minimal.

ACKNOWLEDGEMENTS

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