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# Long-Term Performance of Bridge Approach Remedies Implemented at Western Mega Site

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## Summary

As part of the heavy axle load (HAL) revenue service mega site testing program, Transportation Technology Center, Inc. has worked closely with Union Pacific Railroad to address bridge approach problems under HAL operations. This included determining root causes of problems related to ballast deck bridges with standard concrete ties and remedies that can effectively address these problems. In September 2007 and June 2009, two bridge locations at the western mega site near Ogallala, Nebraska, were selected for remediation and long-term monitoring of performance. Before remediation, these two locations experienced excessive track geometry degradation, mud pumping, and track component failure that required localized maintenance work on a quarterly basis (approximately 63 MGT). After remediation, no localized maintenance (except regularly programmed surfacing operations for the entire line) has been required to date for more than 1,000 MGT, indicating the aforementioned problems were effectively addressed. This *Technology Digest* is written as a final summary; interim reports can be found in the list of references. The main conclusions are as follows:

- At the western mega site, where the bridges are subjected to 220–250 MGT of HAL traffic annually, some ballast deck concrete tie bridges and their approaches have experienced more rapid track geometry degradation, mud pumping, and track component failures than the adjacent open track. Dynamic wheel loads three times as high as the static wheel loads have been recorded at the western mega site.
- The main root causes of these problems were determined to be high track stiffness and low track damping for the track on the bridges, which adversely affected dynamic vehicle-track interaction when differential track settlement started to occur at the bridge approaches. Some of these ballast deck bridges with concrete ties had track modulus measured at 12,000 lb/in/in, which is considered too high to accommodate dynamic vehicle-track interaction.
- For ballast deck concrete tie bridges, effective remedies would include reducing track stiffness and increasing track damping for the track on the bridges. In addition, effective drainage would need to be incorporated as part of remediation to prevent mud pumping.
- Two different remedies were implemented for two separate bridges at the western mega site: one used concrete ties fitted with rubber pads on the bottom surface and the other used ballast mats between the ballast layer and bridge deck. Both were intended to reduce track stiffness and increase track damping for the track on the bridge. For both bridges, the ballast section was increased to a minimum depth of 12 inches below the bottom of the ties. In addition, drainage improvement was made to ensure that water would not accumulate on the bridges or in the approaches.
- Long-term performance of these remedies has been excellent, resulting in significant economic benefits from reduction of slow orders, train delays, and major track maintenance activities.

This research is jointly funded by the Association of American Railroads and the Federal Railroad Administration.



**Introduction**

At the western mega site located near Ogallala, Nebraska, on a heavy haul coal route of Union Pacific Railroad (UP), there are many ballast deck bridges (concrete or steel) with standard concrete ties. With high annual tonnage (220 to 250 MGT per year) and 50 mph operating speed for the loaded coal trains, some of these bridges have experienced more rapid track geometry degradation, mud pumping, and track component failure than the adjacent open tracks.

Transportation Technology Center, Inc., in cooperation with UP, has conducted an extensive investigation into the root causes of these problems and effective remedies.<sup>1-5</sup> This *Technology Digest* is written as a final summary of two remedies that were implemented at the western mega site in September 2007 and June 2009, respectively.<sup>2,3</sup>

**Problems and Root Causes**

At bridge approaches, track inherently deforms and settles more due to HAL train operations than the track on the bridge, as a result of the change in track structure from the open track to the bridge. In general, for the track on the bridge, there is less ballast and no subballast, and obviously no subgrade foundation, as compared to the adjacent open track. As a result, differential track settlement (Figure 1 top) would occur along the track, leading to higher dynamic vehicle-track interaction.

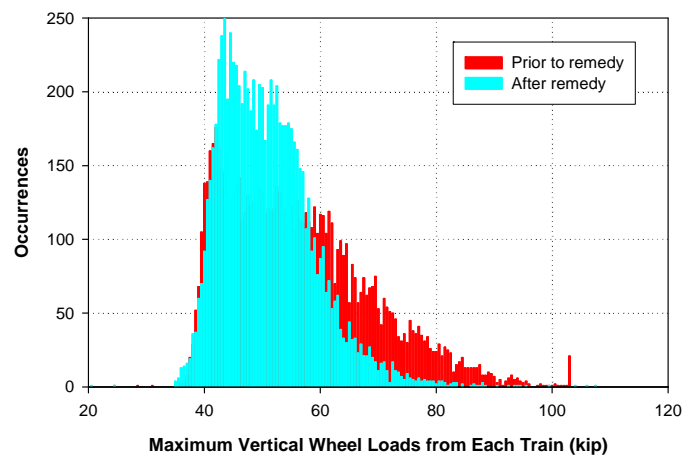


**Figure 1. Rough Track Geometry and Mud Pumping Associated with Bridge Approaches**

When higher dynamic vehicle-track interaction occurs, adequate track resiliency and damping would help to attenuate wheel-rail forces applied on the track. However, for some ballast deck concrete bridges, this was found not to be the case. Ideally, track modulus for the track on the bridge should be similar to what is typically found for the surrounding open track (in this case, between 4,000 and 6,000 lb/in/in) with

standard concrete ties. Measurements, however, have shown that track modulus can be significantly higher than these ideal values, with some track on the bridge having a track modulus as high as 12,000 lb/in/in.<sup>1</sup>

In some cases, development of differential track settlement, in conjunction with high track stiffness and low track damping, produces a vicious cycle, leading to higher dynamic wheel-rail forces, larger differential track settlement, degradation of ballast particles, and mud pumping when track drainage condition is also poor. Figure 1 bottom shows such an example of mud pumping. At one bridge location at the western mega site, measurements of dynamic wheel loads have shown that the maximum dynamic wheel loads generated were three times as high as the static wheel loads (Figure 2 and Reference 2).



**Figure 2. Maximum Dynamic Wheel Loads at a Bridge Location Measured before and after Remediation**

**Remediation**

Based on the findings of root causes, it was determined that an effective remediation method would need to reduce track stiffness and increase track damping for the track on the bridge to the levels consistent with that of open track. In addition, improved track drainage is an essential part of remediation. Note that there was no poor subgrade in the bridge approaches causing problems for the locations investigated at the western mega site. As such, soil improvement and stabilization were not included as part of the remediation.

In September 2007, a short single-span ballast deck concrete bridge was reconfigured with concrete ties fitted with rubber pads on the bottom surface (Figure 3) and, in June 2009 a 3-span ballast deck steel bridge was reconfigured with a ballast mat installed between the ballast layer and the bridge deck (Figure 4). Before remediation, both bridges and their approaches had problems similar to those shown in the photos in Figure 1, which were taken at the second bridge location. As part of the remediation, degraded ballast was replaced with at least 12 inches of new ballast between the bottom of the ties and the surface of the bridge deck. The ballast section of the 3-span steel bridge, which had a minimum depth of 10 inches before remediation, was replaced with a 14.5-inch section.

At both bridge locations, measures were taken to ensure proper drainage for the track on the bridge as well as in the approaches.



Figure 3. Concrete Ties Fitted With Rubber Pads



Figure 4. Ballast Mats for a Bridge at Western Mega Site

### Long-Term Performance

Performance monitoring at these two bridge locations included dynamic response measurements under train operations, periodic inspections of track conditions, analysis of track geometry degradation from the records of track geometry inspection vehicles, and maintenance records before and after the remediation was implemented for both bridges.

At the first bridge location, dynamic responses (i.e., wheel-rail forces, vibration of rails and ties, and bending strains of concrete ties and bridge beam) were measured before and after remediation.<sup>2</sup> Figure 2 shows a considerable reduction of maximum dynamic impact forces, especially in the range of 60,000 to 105,000 pounds, as a result of improved track geometry, track stiffness, and damping characteristics.

Consistent with what is shown in Figure 2, installation of the remedy led to a considerable reduction in high amplitude vibration expressed in terms of acceleration, e.g., from 50 g to 20 g for the vertical acceleration measured on the rails, as illustrated in Figure 5, indicating improved track component performance. In addition, for bending strains on the bottom surface of the concrete bridge, a 30 percent reduction was achieved by implementing this remedy, as Figure 6 shows, indicating improved bridge span performance.

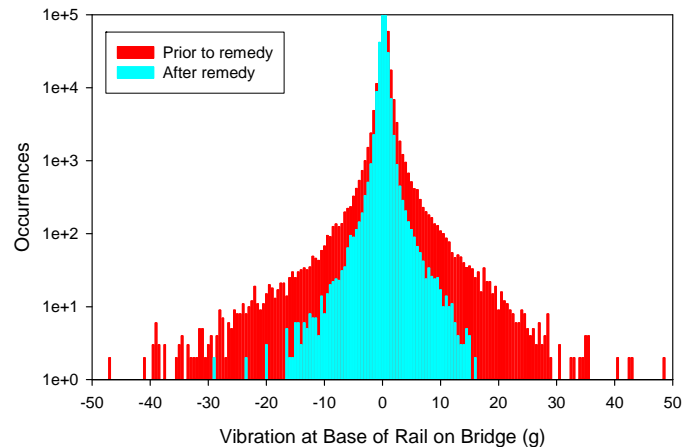


Figure 5. Reduction of Vibration from Remedy

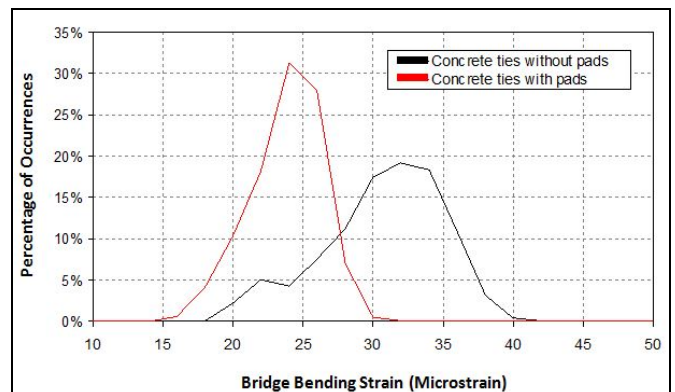


Figure 6. Reduction in Bending Strains from Remedy

When the second bridge location (Figure 7 bottom) was selected for remediation, a third bridge 12 miles away with a similar design was also selected as a control test location, which only went through conventional ballast undercutting and tamping operations to remove degraded ballast and correct rough track geometry. Maintenance at this third bridge coincided with the installation of the ballast mats and drainage improvements at the second bridge.

Figure 7 (top) shows rough track geometry already developing at the third bridge location only two months after the conventional undercutting and tamping operations. In contrast, Figure 7 (bottom) shows that good track geometry was sustained two years after the remediation at the second bridge location.

MP 80.5, two months (40 MGT) after conventional undercutting maintenance



MP 78.2, two years (480 MGT) after ballast mat/drainage installation

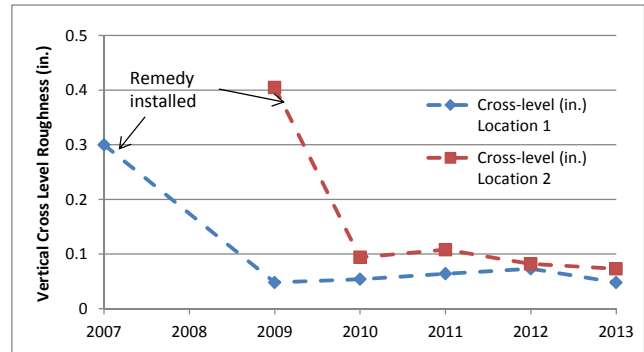


**Figure 7. Comparison of Track Geometry between Two Bridges (One with Remediation and the Other without)**

These two locations that have implemented remediation have not needed any localized major track maintenance inputs (which were required on a quarterly basis), except the regularly programmed out-of-face tamping operations that went through this entire route (on a yearly basis). To date, the first bridge location has accumulated approximately 1,500 MGT, with only hairline cracks observed around 1,200 MGT for some ties on the bridge.

The second bridge location has accumulated 1,000 MGT to date without any major issues.

Figure 8 shows improvement of track geometry conditions. In Figure 8, track cross levels measured from track geometry inspection vehicles were processed as roughness from the years (2007 and 2009) when the installation of rubber pad and ballast mat remedies were completed. Both bridge locations show track surface geometry conditions have improved during the time the two remedies were implemented.



**Figure 8. Track Geometry Roughness Improvement for the Two Locations Implemented with Remedies**

## Acknowledgements

The research presented in this digest is funded jointly by AAR and FRA. As the host railroad of the western mega site, UP provided support essential to the implementation of remedies.

## References

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