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Bridge Approach Remedies Implemented at Western Mega Site

SUMMARY

As part of the heavy axle load (HAL) revenue service mega site testing program, the Transportation Technology Center, Inc. (TTCI) has worked closely with the Union Pacific Railroad (UP) to address bridge approach problems under HAL operations.

The testing program targeted two bridge locations at the western mega site (located near Ogallala, NE, on a heavy haul coal route of UP) for remediation and long-term performance monitoring. One location was selected in September 2007, while the other was selected in June 2009.

Before remediation, these two locations required localized maintenance work on a quarterly basis (approximately 63 Million Gross Tons [MGT]) due to excessive track geometry degradation, mud pumping, and track component failure—see Figure 1. After remediation, no localized maintenance (except regularly programmed surfacing operations for the entire line) was required for more than 1,000 MGT, which indicated that the problems were effectively addressed.

It was discovered that both bridge locations had problems with high track stiffness and low track damping at the track on the bridges, which adversely affected dynamic vehicle-track interaction when differential track settlement started to occur at the bridge approaches.

The two bridges were given different remediation strategies: concrete ties fitted with rubber pads on the bottom surface were used for one location, and ballast mats between the ballast layer and bridge deck were used for the other. Both strategies were designed 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 benefits such as reductions in slow orders, train delays, and major track maintenance activities.

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

BACKGROUND

At the western mega site, there were 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 bridges experienced more rapid track geometry degradation, mud pumping, and track component failure than the adjacent open tracks.

PROBLEMS AND CAUSES

The track at bridge approaches inherently deforms and settles more under HAL train operations than the track on the bridge, since the track structure is changing from the open track to the bridge. In general, for the track on the bridge, there is less ballast, no subballast, and obviously no subgrade foundation, as compared to the adjacent open track. As a result, differential track settlement (see Figure 1) occurs along the track, leading to higher dynamic vehicle-track interaction.

When higher dynamic vehicle-track interaction occurs, adequate track resiliency and damping would help 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.

In some cases, differential track settlement, in conjunction with high track stiffness and low track damping, can produce a vicious cycle that leads to higher dynamic wheel-rail forces, larger differential track settlement, degradation of ballast particles, and mud pumping when the track drainage condition is poor. Figure 1 shows an example of mud pumping. At one of the western mega site bridge locations, the maximum dynamic wheel loads generated was three times as high as the static wheel loads (Figure 2).

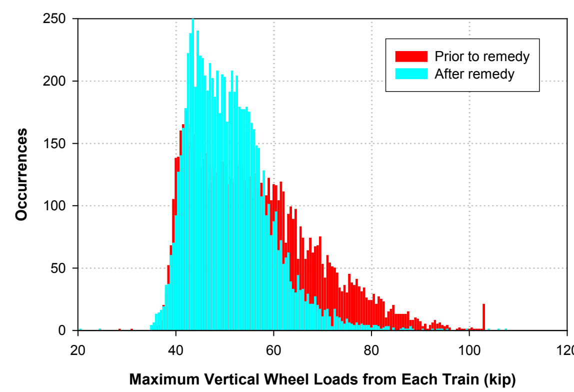

Figure 2 - Maximum Dynamic Wheel Loads at a Bridge Location Measured Before and After Remediation

REMEDIATION

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 be at 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 top) 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 3 bottom). 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. At both bridge locations, measures were taken to ensure proper drainage for the track on the bridge as well as in the approaches.

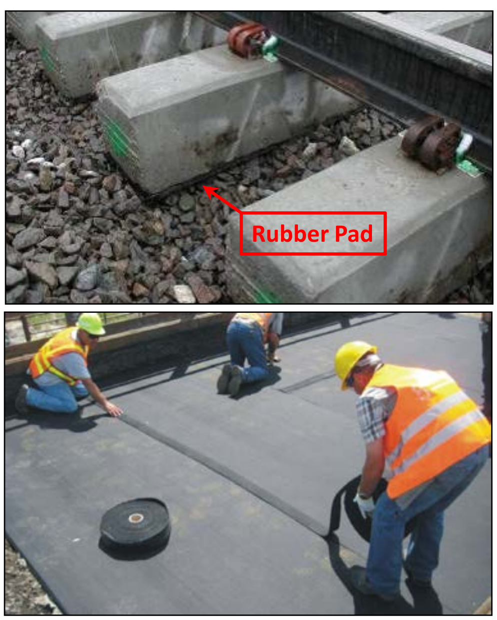

Figure 3 - Concrete Ties Fitted with Rubber Pads (Top) and Ballast Mat Installation (Bottom)

LONG-TERM PERFORMANCE

Performance monitoring 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 were measured before and after remediation and as a result of improved track geometry, track stiffness, and damping characteristics, Figure 2 shows a considerable reduction of maximum dynamic impact forces, especially in the range of 60,000 to 105,000 pounds.

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 4, indicating improved track component performance.

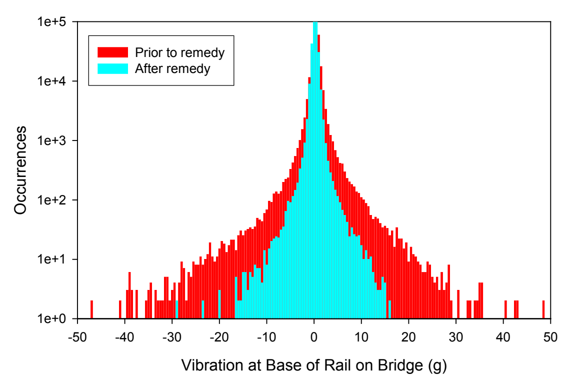

Figure 4 - Reduction of Vibration from Remedy

These bridge locations have not needed any localized major track maintenance inputs (which had been required on a quarterly basis), except the regularly programmed out-of-face tamping operations that went through this entire route (on a yearly basis). As of May 2014, 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 without any major issues.

In Figure 5, 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 that track surface geometry conditions have improved during the time the two remedies were implemented.

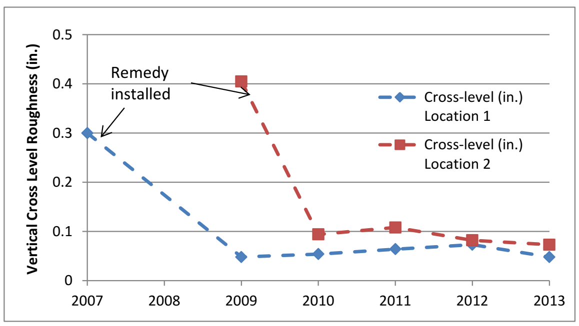

Figure 5 - Track Geometry Roughness Improvement for Two Locations with Remediation

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Heavy axle load (HAL), track transition, bridge approach