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Bridge Approach Remedies in Revenue Service

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Summary

As part of the revenue service mega site testing program, Transportation Technology Center, Inc. (TTCI) has conducted extensive studies and field tests to investigate root causes of problems and has selected, installed, and evaluated various remedies. Early tests have determined root causes of problems for open deck steel bridges located in sharp curves at the eastern mega site, as well as ballasted deck concrete bridges with concrete ties at the western mega site.[1,2] Since September 2007, the focus of the test has been on problem remediation. This *Technology Digest* provides an update of the latest results from this research.

At the eastern mega site, a remedy that has proven effective was to change from open deck to ballasted deck to address issues of abrupt lateral track strength and stiffness changes as well as cross-level differential track support on two bridges located in sharp curves. At the western mega site, an effective remedy was to replace standard concrete ties on a bridge with concrete ties fitted with rubber pads on the bottom of ties to reduce stiffness and increase damping, thus reducing impact forces exerted on the track.

TTCI is also investigating cost effective remedies, as an alternative to deck replacement, to address problems mainly caused by weak subgrade for bridge approaches at the eastern mega site. For bridge approaches at the western mega site, TTCI is investigating other remedies to reduce stiffness and increase damping for the track on bridge; e.g., using ballast mats.

The eastern mega site is located near Bluefield, West Virginia, on a heavy haul track of Norfolk Southern Railway, and the western mega site is located near Ogallala, Nebraska, on a heavy haul track of Union Pacific Railroad.

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INTRODUCTION

A bridge approach often refers to the track within 100 feet of the end of a bridge. However, bridge approach problems refer to all those that appear in approaches as well as in the track on bridge.

Bridge approaches are locations that often require frequent track maintenance, especially under heavy axle load (HAL) train traffic. As part of the revenue service mega site testing program, TTCI has conducted extensive studies and field tests to investigate root causes of problems and has selected, installed, and evaluated various remedies. Early tests have determined root causes of problems for open deck steel bridges located in sharp curves at the eastern mega site, as well as ballasted deck concrete bridges with concrete ties at the western mega site.[1,2] Since September 2007, the focus of the test has been on problem remediation.

At the eastern mega site, a remedy that has proven effective was to change from open deck to ballasted deck to address issues of abrupt lateral track strength and stiffness changes as well as cross-level differential track support on two bridges located in sharp curves. At the western mega site, an effective remedy was to replace standard concrete ties on a bridge with concrete ties fitted with rubber pads on the bottom of ties to reduce stiffness and increase damping, thus reducing impact forces exerted on the track.

EASTERN MEGA SITE

Root Causes of Problems

The eastern mega site is located near Bluefield, West Virginia, on a Norfolk Southern (NS) heavy haul route. This site has many open deck steel bridges. Some bridges in sharp curves often experience rapid track geometry degradation, not only in vertical surface, but also in lateral alignment. As a result, frequent surfacing and aligning maintenance is required, and in the worst case more than once a month, under an annual tonnage of approximately 55 MGT. Other associated track problems include broken spikes and plate cutting on wood ties.

The root causes of these problems were determined to be cross-level differential support over approximately five ties at the ends of bridges, because of skewed back walls (abutments) and large changes in lateral track strength and stiffness from the bridges to their approaches. In some cases, weak subgrade soils in the approaches have also contributed to problems. An earlier TD summarized the findings concerning these problems and their root causes.[1]

Remediation

To address the root causes and mitigate the problems, NS, with support from TTCI, selected two bridges for remediation. One bridge is located at mile post (MP) 352.2, in the body of a 10-degree curve. The other bridge is located at MP 349.1, in the body of an 11-degree curve. Both bridges and their approaches had significant track geometry degradation problems as described previously.

The remedy selected was to change from open deck to ballasted deck, which resulted in two important improvements: The lateral track strength (panel shift strength at the tie-ballast interface and gage strength at the rail-tie interface) is now consistent from the bridge to the approaches, which allows the track on the bridge to move laterally, due to temperature change, in a consistent manner with the track in the approaches. Further, there is now a smooth ballast layer transition from the approaches to the bridge, eliminating the cross-level differential support issue due to the skewed back wall.

Figure 1 shows the bridge located at MP 352.2 before and after deck replacement. Prior to implementing this remedy, ties on the bridge were fixed to the deck and the rails were fastened to the ties with elastic fasteners. In addition, tie spacing was smaller on the bridge than in the approaches, all of which led to inconsistent lateral track strength from the bridge to its approaches. When the track in the approaches moved laterally due to temperature changes, which can be as large as several inches in a sharp curve, the track on the bridge could not move, thus leading to misalignment. Over time, the misalignment would not only grow and worsen but would also cause significant vehicle/track interaction problems.

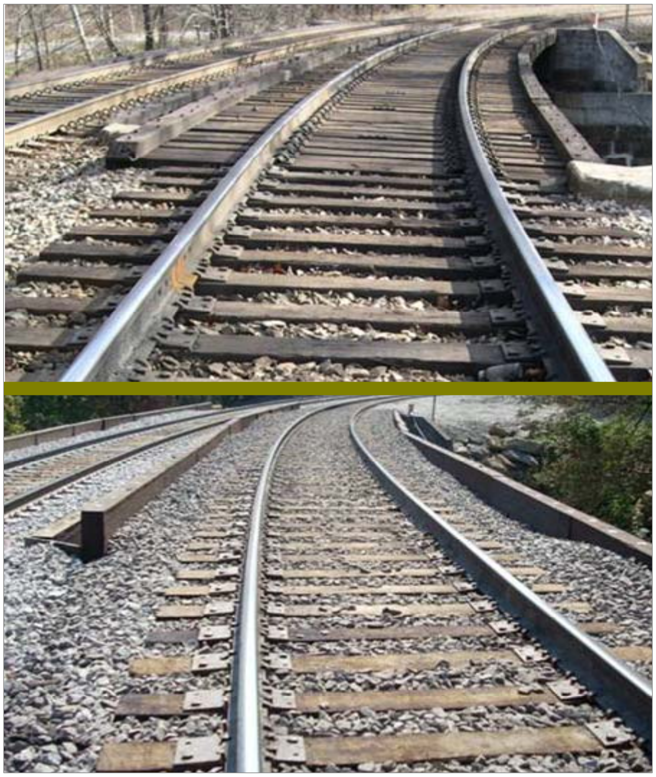

Figure 1. Open Deck (top) to Ballasted Deck (bottom)

As a result of the deck replacement, the track is now essentially the same from the approaches to the bridge, allowing the track to deform laterally in the same manner. In addition, this remedy has eliminated the cross-level differential support issue, because the ballast now supports all ties at the ends of the bridge.

Performance Results

The replacement was completed in September 2007 for the bridge located at MP 352.2 and in March 2008 for the bridge located at MP 349.1. To date, both bridges and their approaches have performed well under HAL traffic, requiring little track maintenance.

Figure 2 shows a comparison of lateral gage strength measured for the bridge located at MP 352.2 and its approaches. Prior to deck replacement, delta gage (loaded track gage minus unloaded track gage under constant vertical and lateral test loads) was significantly lower for the track on the bridge than for the track in the approaches. In other words, the track on the bridge had higher gage strength than the track in the approaches. After deck replacement, gage strength is now more consistent.

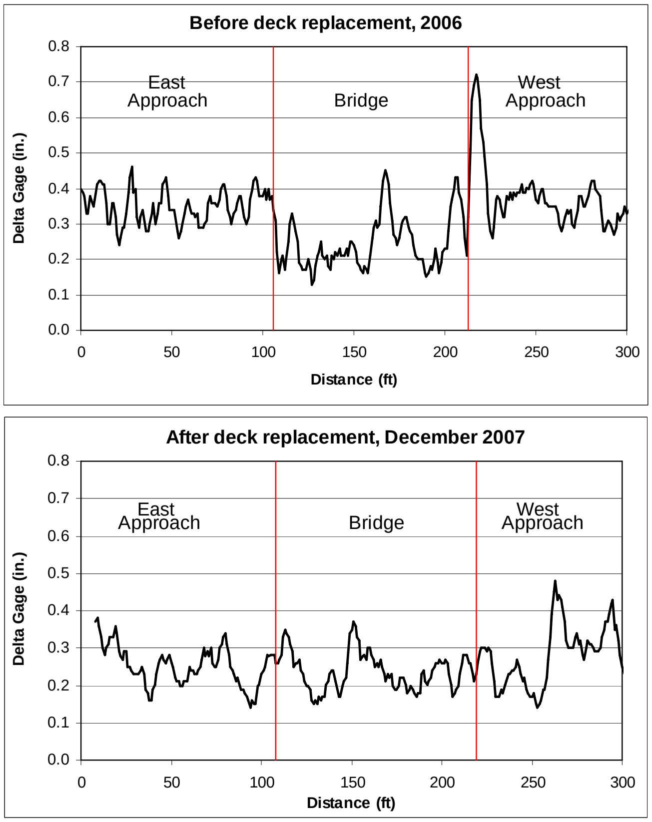

Figure 2. Gage Strength Comparison

Figure 3 shows track geometry performance for the bridge at MP 349.1 and its approaches. Lateral misalignment is shown in terms of roughness, which is a mean square calculation based on actual track geometry car alignment data. As shown, alignment roughness was significantly higher before the remedy was implemented. Similarly, track geometry in vertical plane (surface and cross level) has improved greatly.

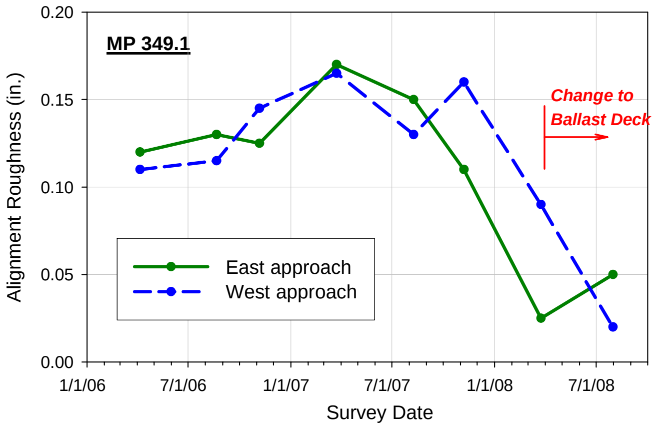

Figure 3. Reduction of Alignment Roughness from Remedy

WESTERN MEGA SITE

Root Causes of Problems

The western mega site is located near Ogallala, Nebraska, on a UP heavy haul coal route. This site has many ballasted deck concrete and steel bridges. Some bridges that use standard concrete ties often experience mud pumping from ballast breakdown and cracked concrete ties. Wheel impact loads on one of these bridges measured three times higher than static wheel loads. The western mega site has very high tonnage, approximately 250 MGT a year.

The root causes of these problems were determined to be high stiffness and low damping for tracks on these bridges.[2] In some cases, track modulus on the bridge was measured more than twice as high as that in the approaches.

Remediation

Based on results from a test on a ballasted deck concrete bridge with concrete ties at Facility for Accelerated Service Testing (FAST), an effective remedy for these problems was determined by reducing track stiffness and increasing track damping for the track on the bridge.[3] A number of methods have been tested at FAST, including the use of concrete ties fitted with rubber pads on the bottom of ties, wood ties, plastic ties, or ballast mats, all of which have led to improved track performance.

Union Pacific, with consultation from TTCI, decided to test a remedy using concrete ties fitted with rubber pads on the bottom of the ties. In September 2007, standard concrete ties on a short span concrete bridge were replaced with ties fitted with rubber pads. Also, as part of the track work, fouled ballast was replaced and track drainage was improved.

Performance Results

Before implementation of the remedy, this bridge and its approaches had significant problems with ballast breakdown, mud pumping, cracked concrete ties, and an incident of a broken rail.[2] Since installation of the remedy in September 2007 and for more than 430 MGT of HAL traffic, track performance has been good, without any of the past problems.

Figure 4 shows the reduction in wheel impact forces measured using the instrumentation at this test location. Each histogram is a summary of maximum wheel loads recorded from a large number of passing trains. As shown, there has been a significant reduction in large impact forces as a result of this remedy, especially in the range of 60,000 to 105,000 pounds.

As part of these measurements, vibration of the track was recorded at various track locations before and after remediation. Figure 5 shows a comparison of the vertical vibration results taken at the base of the rail for the track on the bridge. Consistent with what is shown in Figure 4, installation of the remedy led to a significant reduction in high amplitude vibration expressed in terms of acceleration.

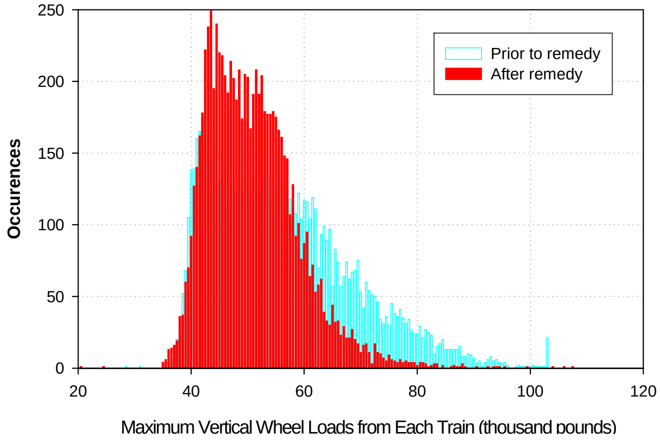

Figure 4. Reduction of Impact Forces from Remedy

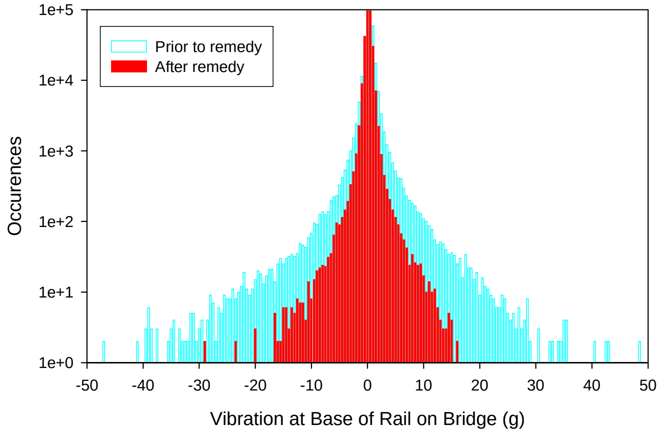

Figure 5. Reduction of Vibration from Remedy

Strain gages were installed on the bottom surface of the concrete bridge at the center of the span. Figure 6 shows the reduction in bending strains measured under HAL train traffic. On average, a 30 percent reduction in dynamic bending strains was achieved by implementing this remedy.

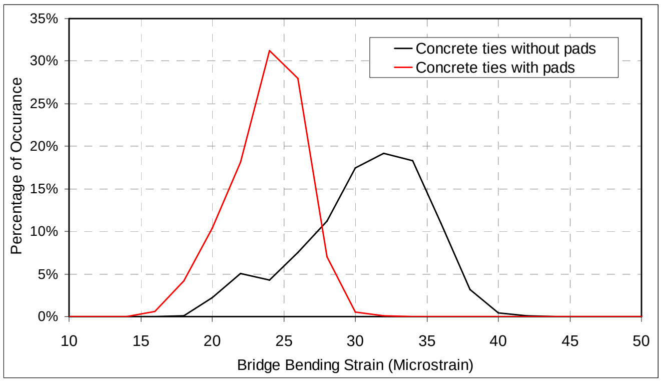

Figure 6. Reduction in Bending Strains from Remedy

FUTURE WORK

At the eastern mega site, TTCI is currently investigating alternative potentially less costly remedies as compared to deck replacement, as well as others that can address bridge approach problems mainly caused by weak subgrade.

At the western mega site, TTCI is currently investigating alternative remediation methods such as the use of ballast mats to reduce stiffness and increase damping for the track on the bridge, thus reducing impact forces exerted on the track.

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TTCI engineers Rafael Jimenez and David Williams, and TTCI consultant Jim Hyslip contributed significantly to the research presented in this digest.

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