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Vertical Track Stiffness Tests of Revenue Service Bridges and Approaches

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Summary

Transportation Technology Center, Inc.'s (TTCI) Track Loading Vehicle (TLV) was used to investigate the causes of and remedies for track geometry degradation and concrete tie cracking associated with four ballasted deck concrete bridges and their approaches.

The Union Pacific (UP) and TTCI collaborated to conduct track stiffness testing on a revenue service line. Conclusions drawn from these tests were:

- The track structure on all four concrete bridges had high vertical track stiffness (on average the track modulus was approximately 10,000 lbs/in./in), resulting in an adverse condition for vehicle/track dynamic interaction. In comparison, track modulus measured on a steel bridge with wood ties (ballast deck) averaged 4,000 lb/in./in.
- Change in track stiffness from the concrete bridges to their approaches was very high for all four bridges (typically by a factor of 2), causing or contributing to dynamic vehicle/track interaction and truck geometry degradation in the approach areas.
- To solve the problems associated with these bridges, the most effective solution should be to reduce the stiffness characteristics of the track on the bridges.

Based on the results and conclusions from this investigation, UP has decided to take measures to improve the track stiffness characteristics of these four bridges. One of the measures under consideration is to install rubber pads under the concrete ties on the bridges. A test¹ conducted at the Transportation Technology Center showed that the use of rubber pads under concrete ties reduced track modulus from 8,900 to 2,100 lbs/in./in.

After the remediation measures are complete, TTCI engineers will go back and repeat the track stiffness tests on these four bridges. In addition, track geometry and tie performance will be monitored to examine the effects of these remediation measures. ■

Suggested Distribution:

- Maintenance-of-Way
- Track Maintenance
- Planning & Analysis
- Safety

INTRODUCTION AND BACKGROUND

In cooperation with the UP, TTCI recently conducted track stiffness testing on a revenue service line. The objective was to investigate the causes of and remedies for track geometry degradation and concrete tie cracking associated with four ballasted deck concrete bridges and their approaches.

Bridge approach locations are often associated with accelerated track geometry degradation. Other associated track problems include pumping ballast, swinging or hanging ties, rapid ballast degradation, rail battering and fatigue, wood-tie plate cutting, and concrete tie cracking. These problems also cause increased dynamic wheel loads, leading to wear and tear on vehicle components and contributing to poor ride quality.

Many factors can cause and contribute to the above-mentioned problems. Extremely stiff track on bridges and abrupt track stiffness changes at bridge approaches are two main factors. Obviously, an overly stiff track is adverse to dynamic vehicle/track interaction, and large and rapid changes in track stiffness leads to uneven track deflections that can cause large dynamic wheel/rail forces. These increased forces cause uneven settlement, which leads to even higher forces.

TEST SITE DESCRIPTION

The test sites are on a UP revenue service line. Included are four ballasted deck (average ballast depth is 15 inches) concrete bridges. These four bridges are located on the same mainline track and are constructed with concrete ties and elastic fasteners. The rails are 133RE type. The four bridges were built in 1999, and their approaches were constructed with four different track foundation types:

- 8-inch hot mix asphalt (HMA) underlayment, 100 feet long
- 8-inch geocell subballast reinforcement, 100 feet long
- 6.75-foot-deep cement stabilized backfill, 10 feet long having a 2:1 taper upward
- Standard track construction (12-inch ballast on a compacted embankment)

The first three foundation types were intended to strengthen the approach track and the fourth type was intended as a control section for comparison purposes. This revenue service line has a significant amount of traffic with 70 percent heavy axle loads (>263k) at roughly 163 MGT per year.

However, none of the three strengthening methods improved track performance compared to the control section.² Significant track geometry degradation at the approaches required frequent surfacing operations (e.g., 4 to 7 inches of cumulative track raises during the first 80 MGT). In addition, the concrete ties on the bridges started to crack and exhibit early fatigue failure problems.

To help determine the causes of and remedies for geometry degradation at the approaches and concrete tie cracking on the bridges, the TLV was employed to characterize track stiffness conditions for these bridges and their approaches.

In addition to these four concrete bridges, a ballasted deck steel-beam bridge was tested. This bridge is located in the same area but on an adjacent track, which has traffic of 50 MGT per year. Wood ties are used on this bridge. No significant geometry deviation was reported for this bridge.

TEST METHOD

The newly developed TLV in-motion vertical track stiffness technique was used for this investigation.³ During an in-motion vertical track stiffness test at 10 mph, the TLV load bogie applies a constant vertical load (40-kip wheel force) to the track while measuring the corresponding track deflection profile. Measured track deflections are used to characterize vertical track support. Under a constant test load, higher deflection indicates lower track stiffness, and vice versa. In addition, variations in the track deflection profile relates to the variation of track stiffness.

If dynamic (in-motion) track modulus is to be determined, a second run under a 10-kip wheel force is performed to quantify deflection components due to rail/tie voids. The difference in the two profiles then gives deflections that are used to calculate dynamic track modulus. Dynamic track modulus is determined by the following equation (theoretical value):

$$u = (30000/y)^{4/3}/(64EI)^{1/3}$$

where: y = Deflection profile
 EI = Rail bending stiffness

TEST RESULTS

Dynamic Track Modulus

Figures 1-4 give dynamic track modulus test results for the four concrete bridges and their approaches. As mentioned earlier, these four bridges have experienced concrete tie cracking problems, and all the approaches have had significant geometry degradation, regardless of which stabilization method was used to strengthen the approach area.

A detailed discussion of the test result for each bridge is given below. In general, the test results showed that the track structure on these bridges had high stiffness characteristics. On average, the measured track modulus on these bridges was approximately 10,000 lbs/in/in, which is too high to accommodate desirable vehicle/track dynamic interaction. In addition, the change in track stiffness from bridge to approach is too high (on average by a factor of 2). These two factors alone may have caused, or contributed to the problems associated with these bridges.

Figure 1 shows the test results for the bridge with the standard approach construction (control section). As illustrated, track modulus measured on the bridge varied from 9,000 to 12,000 lbs/in/in. For the two approaches, measured track modulus varied from 5,000 to 7,000 lbs/in/in.

Figure 2 shows the test results for the bridge with geocell stabilized approaches. As illustrated, track modulus measured on the bridge ranged from 8,000 to 11,000 lbs/in/in. For the two approaches, track modulus was around 4,000 lbs/in/in, although the west approach had more variation in track modulus.

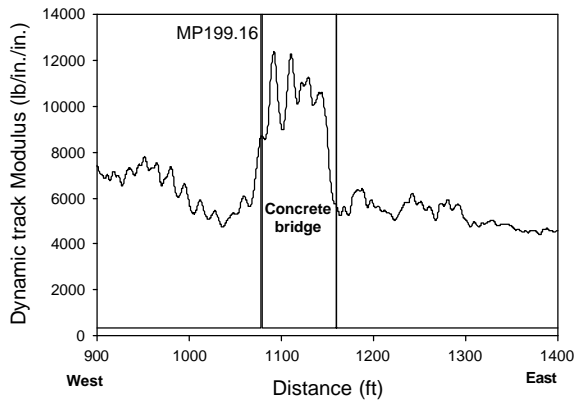


Figure 1. Bridge with Control Approaches

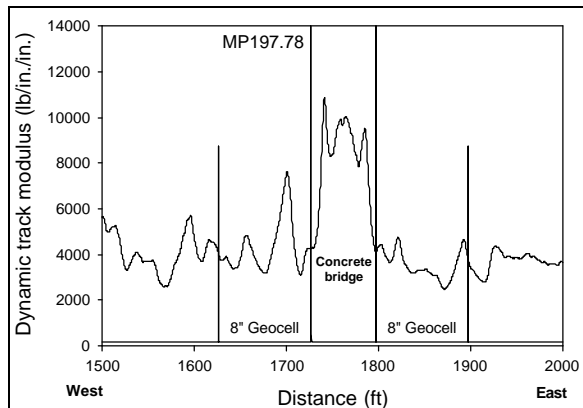


Figure 2. Bridge with Geocell Stabilized Approaches

Figure 3 shows the test results for a longer bridge with the approach stabilized using HMA underlayment. Again, the measured track modulus on the bridge was high, ranging between 9,000 and 11,000 lbs/in/in. For the approaches, measured track modulus was around 6,000 lbs/in/in. Similar to the first two bridges, a large change of track stiffness from bridge to approach is obvious.

Figure 4 shows the test results for the shortest bridge among the four tested. For this bridge, the two approaches were stabilized using a cement stabilized backfill, 6.75 feet deep, 10 feet long with 2:1 upward taper (as illustrated in Figure 4). Obviously, the use of a thick stabilized layer increased track stiffness (6,000-8,000 lbs/in/in). However,

because of the high stiffness of the track on the bridge, the change in track stiffness from bridge to approach is still significant.

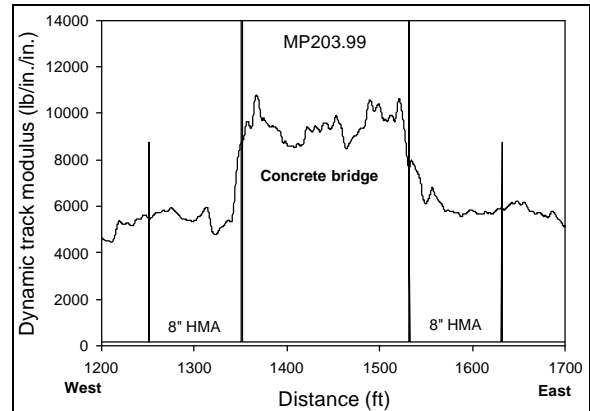


Figure 3. Bridge with HMA Stabilized Approaches

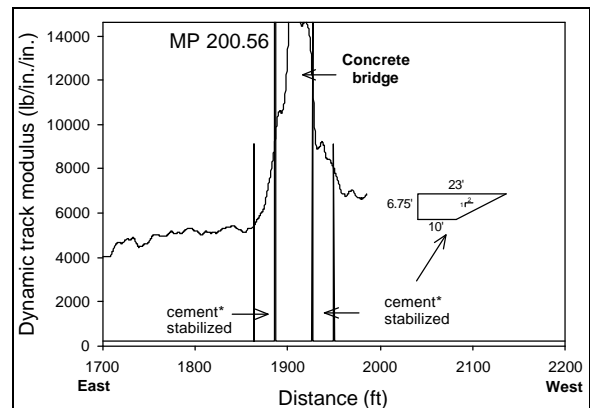


Figure 4. Bridge with Soil Cement Backfill Approaches

Ballast Deck Steel Bridge with Wood Ties

For comparison, dynamic track modulus tests were also conducted on a wood tie steel beam bridge and its approaches, located in the same area but on an adjacent track. Figure 5 shows the test results.

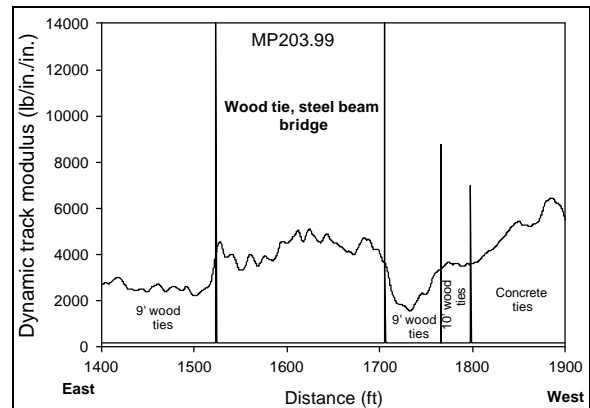


Figure 5. Ballast Deck Steel Beam with Wood Ties

As illustrated, track modulus measured on the bridge ranged from 3,500 to 5,000 lbs/in./in, much lower than those measured on the four concrete bridges with concrete ties. In the open track, the east approach with wood ties had a track modulus around 2,600 lbs/in./in. In the west approach, the first 100 feet of track has wood ties, after which concrete ties are used. As observed in this graph, there is a gradual but significant increase in the track modulus when the track foundation changes from wood to concrete ties.

Track Deflection Profile

Figure 6 shows the deflection profile results obtained under 40-kip wheel loads for three concrete bridges. Note that deflection results include not only the contribution from track substructure, but also the contribution from rail/tie voids. As illustrated, the approaches showed large and variable track deflections (i.e., bumps or dips), indicating apparent geometry and vertical strength degradation in these areas.

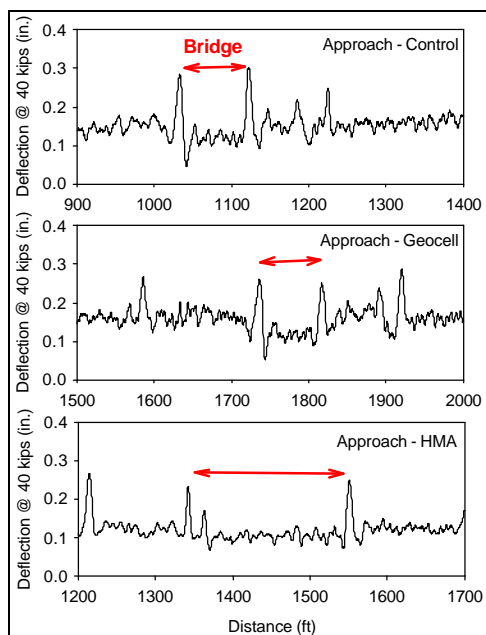


Figure 6. Bumps and Dips at Bridge Approaches

CONCLUSIONS AND FUTURE WORK

The track stiffness results described in this document leads to the following conclusions:

- The track structure on all four concrete bridges had high vertical track stiffness (on average, the track modulus was approximately 10,000 lbs/in./in), resulting in an adverse condition vehicle/track dynamic interaction. In comparison, track modulus

measured on a steel bridge with wood ties (ballast deck) averaged 4,000 lb/in./in.

- Change in track stiffness from the concrete bridges to their approaches was very high (on average by a factor of 2) for all four bridges, causing or contributing to adverse dynamic vehicle/track interaction and track geometry degradation at the approach areas.
- To solve the problems associated with these bridges, the most effective solution should be to reduce the stiffness characteristics of the track on the bridges.

Based on the results and conclusions from this investigation, UP has decided to take measures to improve the track stiffness characteristics of these four bridges. One of the measures under consideration is to install rubber pads under the concrete ties on the bridges. A test¹ conducted at Transportation Technology Center showed that the use of rubber pads under concrete ties reduced track modulus from 8,900 to 2,100 lbs/in./in.

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Acknowledgements

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