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Investigation of Open Deck Bridge Transition Issues at the Eastern Mega Site

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Summary

In 2005 and 2006, engineers from the Transportation Technology Center, Inc. (TTCI) and Norfolk Southern (NS) investigated track transition issues associated with open deck steel bridges at the eastern mega site, located on a NS mainline at the Virginia Division, mile post (MP) N350-360. Six open deck steel bridges and their approaches were investigated to determine what factors have caused and contributed to the high degradation modes at these track transition areas. The investigation was the first phase of the study to accurately document problems, with the next phase aimed at designing and testing remedies to mitigate transition problems.

The track transition problems at the eastern mega site include rapid geometry degradation in both alignment and surface, broken spikes and fasteners, plate cutting, and broken rails. Maintenance is required frequently; in some cases more than once per month. The investigation has shown that the following factors, often in combination, have caused or contributed to the problems:

- Differential track support of left and right rails for approximately five ties off of the bridge. The skewed back wall (abutment) at the ends of the bridge results in one side of the ties being supported on the bridge girder, whereas the other ends of the ties are supported on the approach ballast. The skewed back wall also contributes to ineffective surface maintenance in these areas, often leaving the approach ends of ties unsupported.
- As indicated by cone penetrometer testing (CPT), several of the approach tracks have weak subgrade. The testing indicated large ballast layers, often 6 to 8 feet thick, as a result of frequent tamping operations. The soft subgrade also contributes to the track stiffness transition issue, that is, the bridge track structure is stiffer than the approach track.
- There are significant lateral track stiffness transition issues present at these bridges. The difference in lateral stiffness can be attributed to different fastening systems (e.g., elastic fasteners on bridge and cut spikes on approach) and different ways the ties are supported between bridge track and approach track. The bridge acts as a fixed point in the curve, whereas track in the approaches can move laterally a lot more easily, leading to misaligned track from the approaches to the bridge.
- Another contributing factor is the high degree of curvature (up to 10 degrees) and steep grade (up to 1.4 percent), causing higher lateral and longitudinal wheel/rail forces.

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Introduction

Open deck bridge track transitions have presented significant maintenance problems on a NS’s mainline track. As part of a research funded by the AAR and FRA, engineers from TTCI and NS conducted an investigation of six open deck bridges, located at the eastern mega test site (TD05-026) on a NS mainline, MP N350–360, Virginia Division.

This track is subjected to approximately 55 million gross tons (MGT) of traffic annually, with 50 percent of the traffic with heavy axle loads. The bridge approaches at this mega test site have required excessive maintenance due to track transition problems. The problems include rapid geometry degradation in both alignment and surface, broken spikes and fasteners, plate cutting, and broken rails. Maintenance is required frequently; at some bridges it is required more than once a month (5 MGT intervals).

In an attempt to determine the degradation modes, the following five tasks were completed in 2005 and early 2006:

- 1) Analysis of past track geometry car inspection records
- 2) Site inspection with NS track and bridge supervisors
- 3) Vertical track modulus tests using TTCI’s Track Loading Vehicle (TLV)
- 4) Subgrade strength testing using the TLV equipped for the cone penetrometer test (CPT)
- 5) Gage strength testing with FRA’s GRMS test vehicle

As a result of the investigation and discussions with NS personnel, two bridge sites were selected for more detailed analysis and subsequent designs of track transition solutions. The two test sites are discussed in detail in the following sections.

Bridge Approach Test sites

Bridges at MP 352.15:

The two bridges at MP 352.15 on Main 1 and 2 are located in a 10.2 degree curve. Elastic fasteners (Pandrol clips) are used on the bridges, whereas cut spikes are used in the approach tracks. The track construction on the bridges consists of wood ties with 15.5 inch tie spacing. The approach tracks also have wood ties but with 19.5 inch tie spacing.

Bridges at MP 352.81:

The two bridges at MP 352.81 on Main 1 and 2 are located in a spiral to a 10 degree curve. For the east bound (direction of loaded coal cars) traffic, there is a significant downhill grade. At this location, cut spikes are used on the bridge as well as in the approach tracks (Main 1). The track construction on the bridge consists of wood ties with 15.5 inch tie spacing. The approach track has wood ties but with 19.5 inch tie spacing.

Factors and Causes of Problems

Based on the investigation conducted, five major factors have been identified. These have either caused or have contributed to the excessive maintenance requirements for the bridges and their approaches. Table 1 provides a quick summary of how each factor is related to the excessive maintenance problems. Detailed discussions are given in the subsequent sections.

Table 1. Relationship between Factors and Problems

Maintenance Problem	Contributing Factors
Surface issue	<ul style="list-style-type: none"> • Differential support between two rails due to skewed back wall • Vertical track modulus • Weak subgrade • Severe load environment
Alignment issue	<ul style="list-style-type: none"> • Lateral track stiffness • Severe load environment
Broken spike/fasteners, plate cutting, and broken rail	<ul style="list-style-type: none"> • Severe load environment

1. Differential Track Support between Left and Right Rails

One of the major factors contributing to the bridge transition issues at the eastern mega site are skewed bridge back walls. Skewed back walls are used because these bridges cross rivers or roads not perpendicular to the railroad tracks. In general, a skewed back wall requires that approximately five ties at the transition area span both the bridge structure and the approach track.

This creates a differential support between left and right rails, i.e., the side supported on the abutment is much stiffer than the side supported on the ballast. Exemplifying this problem are the ties on the weaker side that are often supported directly on the ground without ballast, as Figure 1 shows. Shimming is often required to compensate for the track settlement on the weaker side.

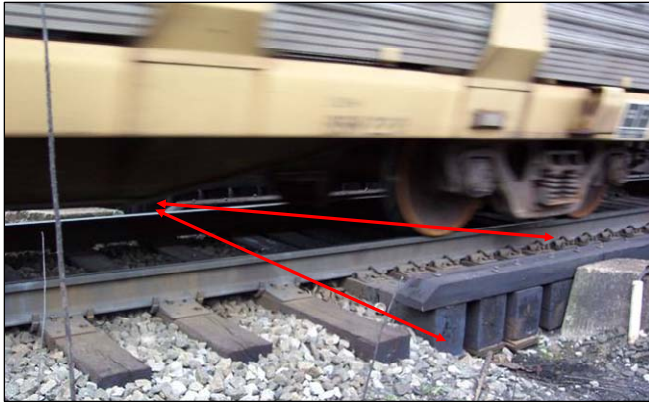


Figure 1. Ties Shimmed and Supported without Ballast, due to Skewed Abutment

Another problem associated with this area is the difficulty of conducting ballast tamping, because on one side ties are supported on the abutment, on the other side ballast particles often roll out.

2. Vertical Track Modulus Change

Figure 2 shows an example of track modulus test results obtained using TTCI's Track Loading Vehicle (TLV). It shows significant modulus variation between the approaches and the bridge. That is, track modulus results measured on the bridges were higher than those measured on the approach tracks. For this bridge at MP 352.15, the change is even more pronounced for the east approach. As found from past research (TD 03-013 and TD 05-001), large changes of track moduli in track transition areas can contribute to the problems in these areas. Furthermore, this approach track has track moduli measured lower than 2,000 psi, indicating weak track support.



Figure 2. Track Modulus Test Result at MP 352.15

3. Subgrade Strength

Figure 3 shows an example of CPT test results, which indicate layer thicknesses and subgrade soil strength. As

shown, the ballast layer thickness (as indicated by large tip resistance) is large (6 feet), obviously as a result of past ballast surfacing and tamping operations. For this bridge, the subgrade at the east approach is weak, as indicated by very low tip resistance (i.e., low soil strength), obviously having contributed to the surface problems requiring frequent tamping in this approach track.

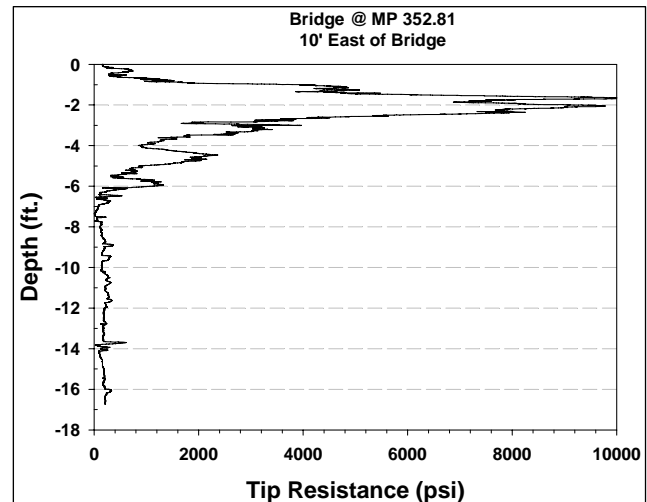


Figure 3. CPT Test Result 10 Feet East of Bridge at MP 352.81

4. Lateral Track Stiffness Change

Another issue associated with open deck steel bridges located in curves or spirals is the lateral track stiffness variation. The approach track and bridge track have a significant difference in lateral stiffness due to the difference in the ways the rails is fastened to the ties and the difference in the way ties are supported on abutment or ballast in an approach. For example, use of elastic fasteners on a bridge, as opposed to the use of cut spikes in the approaches, would contribute to this change of lateral track stiffness.

Figure 4 shows the GRMS test results for the location at MP 352.15. As illustrated, the test results showed a large variation between the bridge and the approaches, with a lot stiffer track on the bridge (in terms of delta gage, i.e., lower delta gage and higher lateral stiffness) than the approach tracks.

What this means is that the track in the approaches can move laterally much more easily than the track on the bridge, leading to a misalignment condition. The track in the approaches could move inches laterally due to temperature change and sharp curvature, while the track on the bridge could move much less because of higher lateral track stiffness on the bridge.

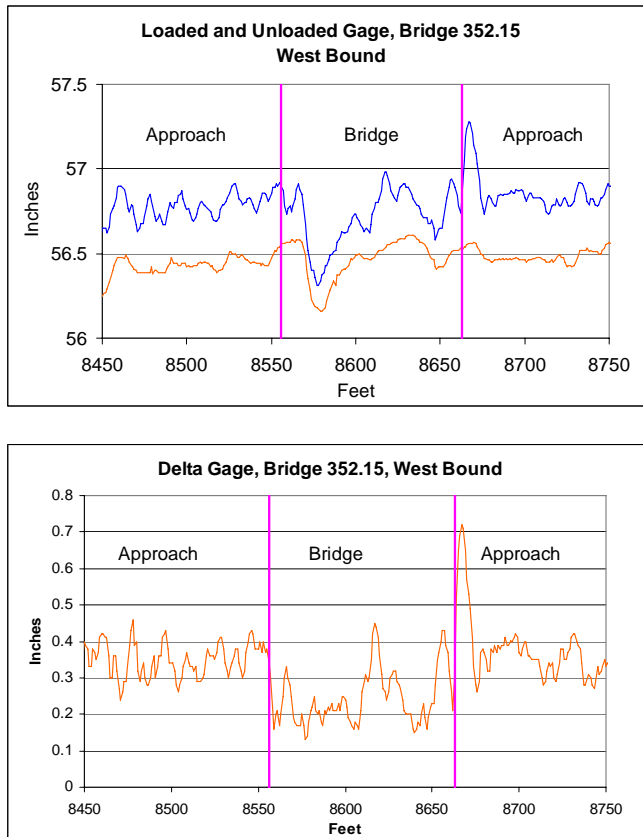


Figure 4. Gage Strength Test Results at MP 352.15

5. Severe Load Environment

In addition to the factors that have been quantified and discussed above, there are other factors that have contributed to the problems associated with the open deck steel bridges and their approaches at the eastern mega site. For example, the load environment in these transition areas is considered to be more severe because of:

- Higher lateral wheel loads due to curving in sharp curves (10 degree)
- Higher longitudinal forces due to braking on the downhill grade (up to 1.4 percent)
- Higher vertical dynamic forces due to dips in the bridge approaches

Field visual observations have shown obvious rocking action of loaded freight cars when exiting from a bridge to its approach track due to the differential support as discussed above. Obviously, a more severe load environment would cause track to degrade more rapidly.

Conclusions and Future Work

Open deck bridge transitions at the eastern mega site have both vertical and lateral issues. The vertical transition issues are complicated by the skewed back walls on these bridges. This causes differential support between right and left rails at the ends of the bridges. Ballast confinement also needs to be addressed to help minimize this differential support. Track modulus on the bridges is approximately 1.5 times that of the approach tracks, contributing to the transition problems. CPT results indicated that there are also soft subgrade issues.

These bridges also exhibit problems with the lateral stiffness change. The bridge acts as a fixed point in the track, whereas tracks in the approaches can move laterally a lot easier, thus causing misalignment conditions. In addition, use of different fastening systems and tie spacing between bridge and approach also contributes to inconsistent lateral track movement.

Work is currently on-going to select, design, install, and monitor the cost effectiveness of remedies to address the transition issues for open deck bridges at the eastern mega site. More geotechnical boring and investigation is planned in the fall of 2006. As to the possible remedies, NS and TTCI engineers have considered a few options, including the following ones to address the excessive track approach maintenance problems:

- Change of open deck to ballast deck should help address the lateral track stiffness issue, and to a secondary degree should help address the vertical track stiffness issue. Consistent ballast support, tie type, tie spacing, and fastening between bridge and approach will make track conditions more consistent in the transition.
- Approach slab, or HMA (hot mixed asphalt), should help address differential track support between the two rails as well as vertical track stiffness issue.

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