

Federal Railroad Administration

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# INVESTIGATION OF RAILROAD BRIDGE APPROACH PROBLEMS ALONG HEAVY HAUL FREIGHT LINES

# SUMMARY

Federal Under a contract with the Railroad Administration (FRA), the University of Illinois at Urbana Champaign (UIUC) is investigating different factors that contribute to the problem of differential movement at railroad track transitions The research objective is to develop new design and rehabilitation methods to mitigate the problem of differential movement at track transitions. In order to achieve this goal, UIUC researchers are using geotechnical instrumentation and performance monitoring equipment to quantify the contributions of different substructure layers to differential movement at railroad bridge approaches. As part of the study, UIUC instrumented two undergrade bridge approaches on Norfolk Southern Railway's (NS) N-Line mainline near Ingleside, WV, to investigate the frequent deterioration in track geometry at these sites. This report provides a brief overview of the instrumentation activity, the data acquisition approach, and preliminary results.

#### BACKGROUND

Railway transitions experience differential movements due to differences in track system stiffness, track damping characteristics, foundation type, and ballast settlement from fouling and/or degradation, as well as fill and subgrade settlement. Identification of different factors contributing towards this differential movement, as well as development of design and maintenance strategies to mitigate the problem, is imperative for the safe and economical operation of both freight and passenger rail networks.

A primary example of differential movement at track transitions involves the development of vertical differential settlements or "bumps" between the railroad bridge decks and approaches. Although several research studies have focused on the mitigation of this differential movement problem, no significant research study has focused on quantifying the contributions of different factors towards the "bump" development.

The current research study involves monitoring the instrumentation and performance of three bridge approaches along Amtrak's Northeast Corridor near Chester, PA. The UIUC research team has been monitoring the performances of the three bridge approaches since August of 2012 and has identified the ballast layers primarily responsible for the bridge approach settlement and the associated differential movement. A second component of this research study involved the instrumentation and performance monitoring of bridge approaches along tracks carrying slow-moving freight trains.

#### OBJECTIVES

The main objective of the NS N-line instrumentation effort was to identify causes of differential movement at track transitions under the passage of slow-moving freight trains and compare them with the factors leading to differential movement under high-speed passenger trains.

#### SITE DESCRIPTION

The two undergrade bridge approaches instrumented during this effort are located at mileposts (MP) 352.2 and 352.8 on the NS N-line mainline between Roanoke, VA, and Bluefield, WV. The bridge at MP 352.2 is located on a 10-degree curve and on a 1.1 percent grade, whereas the bridge at MP 352.8 is located on a 9.7-degree compound curve on a 0.9 percent grade. Since loaded trains move downhill from west to east with full dynamic brake and often with air brakes applied, the track speed in the region is 25 miles per hour. Figure 1 shows one of the bridge approaches instrumented during this effort.





### Figure 1. Instrumentation Drill Rig Setup on Track at the West end of Bridge MP 352.2 on NS N-line

This section of the track is subject to heavy axle load train operations since it sees an annual tonnage of approximately 55 MGT (million gross tons). Historical evidence indicates that these open-deck bridges and their approaches have experienced track geometry degradation (both in the vertical and horizontal directions) and, therefore, require frequent surfacing work. Previously developed track substructure profiles showed these bridge approaches to have significantly thick clay and/or silt layers in the track substructure immediately adjacent to the abutments. Those layers are susceptible to permanent deformation under the slowmoving heavy-haul traffic, leading to differential movements immediately adjacent to the abutment. The bridge at MP 352.2 was modified from an open-deck structure to a ballast deck in the fall of 2007 to remediate the recurrent track geometry problem.

Analyses of track geometry data for the time period between August 2005 and October 2012 indicated that converting the bridge at MP 352.2 from open deck to ballast deck in the fall of 2007 initially helped reduce the vertical surface roughness, but since January 2010 the vertical surface roughness has been increasing. Assuming that there is only minor differential settlement between the ballast on the approach and the ballast on the ballast-deck bridge, some other factors appear to be contributing to the observed differential movement. Accordingly, the current instrumentation effort has been configured to identify and further investigate any additional factors contributing to track profile deterioration.

### **INSTRUMENTATION METHOD**

The primary instruments used in this effort were Multi-Depth Deflectometers (MDDs) and strain gauges. An measures the deformation of MDD individual substructure layers with respect to a fixed anchor buried deep in the ground. The MDD consists of five to six linear variable differential transducers (LVDTs) installed vertically at preselected depths in a small-diameter hole (typically 1 ¾ inch diameter). Typically placed in 10 foot deep holes, MDDs can be used to record both permanent (plastic), as well as transient (elastic), deformations at different depths within the track substructure. For this research effort, researchers modified the MDDs to extend to 18 feet. Figure 2 shows the UIUC team drilling an MDD hole through a wood crosstie.



Figure 2. MDD Hole Drilled through a Wood Crosstie

The instrumentation effort took place between October 15, 2013, and November 1, 2013. Soil samples were collected from different depths during the drilling process for subsequent testing and characterization in the laboratory. Figure 3 shows a sample boring log created during the drilling process, along with the soil types encountered at different depths.



# Figure 3. Example Boring Log Developed in the Field during Drilling

UIUC installed a total of four MDD "strings," two at each of the bridges (MP 352.2 and MP 352.8) using a customdesigned tool to allow individual monitoring of each LVDT throughout the installation process. Each MDD "string" comprised five to six LVDTs, depending on the depth of the hole. Figure 4 shows a photograph of a top MDD module installed within the crosstie to measure deflections within the ballast layer. The researchers also installed strain gauges on the rails to measure the vertical wheel loads and tie reactions. Wheel loads and tie support conditions recorded by the strain gauges are used to analyze the collected data and numerically model the track dynamic loading behavior of the instrumented bridge approaches.

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Figure 4. MDD Module Installed within a Crosstie

# DATA ACQUISITION AND PERFORMANCE MONITORING RESULTS

UIUC will collect data periodically throughout 2014 and monitor the permanent (plastic) as well as transient (elastic) deformations of individual substructure layers, along with time history. The data is being collected with a wayside data acquisition system (see Figure 5). Figure 6 shows a typical vertical wheel load time history recorded by the strain gauges under the passage of a freight train. The differences in weight between loaded and empty cars for the freight train were clearly registered by the strain gauge circuit. Figure 7 shows the corresponding transient responses of the MDD LVDTs under the passage of the same freight train. As shown in the picture, the top LVDT mounted beneath the tie recorded the maximum transient deformations under loading within the ballast layer; these findings were in agreement with previous observations.



Figure 5. Data Acquisition at Instrumented Crosstie

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### Figure 6. Vertical Wheel Load Time History under Typical Freight Train Loading



# Figure 7. Typical Transient Response of LVDTs under Freight Train Loading

# FUTURE RESEARCH TASKS

UIUC researchers will use data collected from these two bridge approaches to validate numerical models designed to identify the different factors contributing to track profile deterioration. Findings from this study will help in the development of new design and rehabilitation techniques to mitigate the problem of differential movement at bridge approaches. This research study is scheduled to end in December 2014.

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# KEYWORDS

Track transition, bridge approach, differential movement, Multi-Depth deflectometer (MDD), strain gauge

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