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Feasibility of Detecting Weak Bridge Stringers Using Onboard Systems

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Summary

Transportation Technology Center, Inc. is investigating the feasibility of using vehicle-based systems to detect bridge impairments. A single vehicle-based system offers the potential to assist with the inspection of hundreds or thousands of railroad bridges, as opposed to a structural health monitoring system that is captive to a single structure.

The focus of this first series of tests was on detecting weak stringers in a trestle bridge. Pilot testing using the Track Loading Vehicle, both the load application and deflection measurement system and the track geometry measurement system, indicate the following preliminary conclusions:

- The deflection measurement under 40,000-pound wheel loads clearly and correctly identified changes in strength of controlled test spans at the Transportation Technology Center (TTC) consisting of rail stringers.
- The rail surface measurement from the track geometry system is able to identify low bridge approaches and changes in track surface over a bridge.
- Both track deflection under load, as well as rail surface track geometry, appear to be key components of an onboard bridge impairment detection system.
- At this point, historical data from past runs is required for comparison.

The testing was performed at the Bridge Deflection Test Facility (BDTF) at TTC, which was constructed to provide adjustable bridge strength and geometry conditions. The BDTF facilitates evaluation, development, and calibration of onboard systems for detection of bridge anomalies. This research was conducted as part of the Association of American Railroads' Strategic Research Initiatives Program on railroad bridges.

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INTRODUCTION

To provide better indication of bridges in need of maintenance or more detailed inspection, Transportation Technology Center, Inc. (TTCI) is investigating the potential for using onboard technology to detect bridge impairment or changes in bridge behavior. Onboard technology offers two potential enhancements to bridge inspection. First, bridges often show behavior under dynamic train loading that is difficult to observe otherwise. Second, an onboard system has the potential to provide observations for hundreds or thousands of bridges, as opposed to a structural health monitoring system that is fixed and capable of monitoring only a single bridge.

In recent years, several railroad industry bridge experts have noted that the location of bridges and/or bridge approaches can sometimes be observed in onboard data, such as track geometry measurements.[1] Various onboard methods had been proposed to measure bridge response. The priority for this study was to investigate the potential use of existing onboard systems to detect bridge defects or significant changes in track support conditions provided by a bridge. This study is first focusing on a very common railroad bridge type, the short-span trestle. Short-span trestles built with steel, concrete, or timber spans are common railway bridges in North America. The focus of this digest is on detecting weak bridge stringers in trestle bridges.

Preliminary Studies on BNSF

BNSF Railway and TTCI studied outputs from several onboard systems for a BNSF line in the vicinity of Pueblo, Colorado, where there are several trestle bridges, most with multiple spans of similar repetitive lengths. The trestles on this line include spans made of steel, concrete, and timber. Testing focused on those with timber or steel spans typically 15 feet or less per span. Data was gathered using the following systems:

- BNSF track geometry car
- BNSF locomotive vehicle and track interaction (VTI) package
- TTCI instrumented freight car (IFC)
- TTCI Track Loading Vehicle (TLV)
- TTCI track geometry system (mounted on the TLV)

These systems represent three basic types of measurements. The geometry systems provide the typical measurements of track surface, alignment, cross level, gage, and related parameters. The VTI and IFC measurements are primarily acceleration-based measurements, which have proven valuable in finding relatively short wavelength defects, especially related to rail surface conditions. The TLV, using vertical loading, can provide measurements related to track deflection and stiffness.

The studies on the BNSF verified that some of these systems are able to sense locations of bridges and/or bridge approaches. The TLV and track geometry systems showed the most promise. The locations of bridges and/or bridge approaches were sometimes visible in the raw data. And the TLV vertical load data also indicated fluctuating responses that corresponded with the span lengths of some of the trestles. But without the ability to change bridge conditions, make repeated runs, or perform a destructive autopsy on a bridge, it was difficult to draw any definitive conclusions from the initial studies on the BNSF. However, some technologies showed good potential. In spite of the use of GPS data, locating bridges accurately enough for detailed analysis was also somewhat of a challenge.

Bridge Deflection Test Facility at TTC

In order to develop, evaluate, and calibrate onboard detection systems for bridges, TTCI constructed an adjustable three-span trestle bridge. The bridge can be configured to provide variable support, in terms of stringer strength as well as pier top support geometry. The bridge generally follows plans for an open deck T-rail span (sometimes called rail top) bridge, with modifications to provide the adjustments desired. Figure 1 shows this new structure, which is known as the Bridge Deflection Test Facility (BDTF). The three spans are each 14 feet in length, for a total length of 42 feet.

Figure 1. BDTF – Adjustable Three-Span Trestle for Evaluation of Onboard Bridge Detection Systems

Pilot Testing on the BDTF

Onboard systems similar to the ones used on the BNSF were also used on the BDTF to determine their feasibility for use in onboard bridge condition assessment. This digest only focuses on the results from the TLV, including both the vertical load testing and the track geometry system. The bridge defect simulated is weak bridge stringers.

Figure 2 shows the TLV passing over the BDTF. The TLV uses an automatic location detector (ALD) system in addition to GPS. For this series of tests, ALD targets were placed at each end of the BDTF to provide positive locations independent of GPS.

Figure 2. TLV Testing on the BDTF

Detection of Weak Stringers using TLV

The BDTF was configured to provide the following three test conditions:

1. Normal condition – all bridge stringers have normal strength
2. Weak center span – both stringers in center span weakened 40 to 50 percent
3. East side of center span weak – one stringer in center span weakened 40 to 50 percent

Figure 3 shows the east rail deflection response as measured by the TLV under a center bogie load of 40,000 pounds per wheel. For this plot and subsequent plots, the BDTF is located from coordinates 100 to 142 feet on the horizontal axis. Responses for all three bridge configurations are shown.

Note that around a distance of 121 feet (the center of the bridge), the deflection under load is noticeably higher for the cases of a weak center span (both stringers) and weak stringer (east rail only), as compared to the deflection with all stringers in normal condition. The cases with the weakened stringers are clearly and correctly identified.

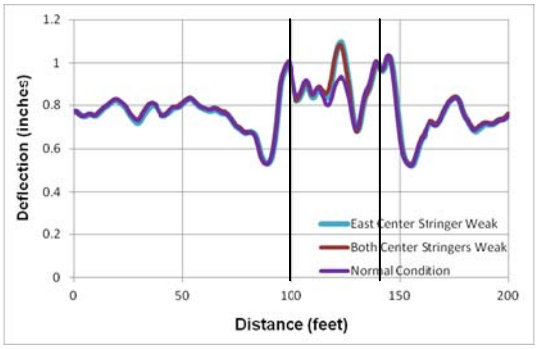

Figure 3. East Rail Deflection Response Measured by TLV under 40,000 lb per Wheel TLV Bogie Load

Figure 4 shows a similar TLV measured response for the west rail under the same three conditions. Again, the weakened stringers are clearly and correctly identified. Note that for the west rail, the increased deflection is shown only for the case of both stringers weak, not for the case of only the east stringer weak. The fact that the west rail deflection measurement is not influenced by the weak stringer under the east rail is encouraging, because it indicates that such a system is capable of isolating and locating a defective member with greater accuracy.

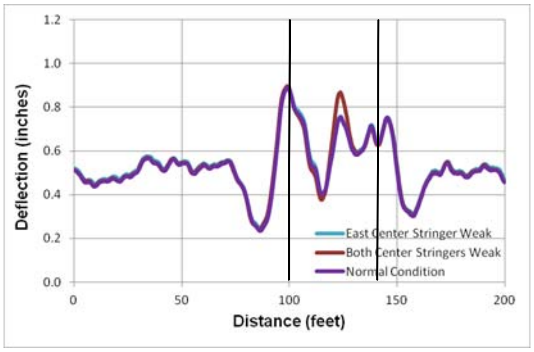

Figure 4. West Rail Deflection Response Measured by TLV under 40,000 lb per Wheel TLV Bogie Load

Figures 5 and 6, the east and west rails respectively, show the differences between the deflection measurements for weak stringers and for stringers in normal condition. In each rail the presence of the weak stringer(s) is clearly and correctly identified using the TLV under the load bogie with 40,000-pound wheel loads on each rail. The signal-to-noise ratio of this measurement seems to be quite high, hopefully providing a good indicator for detecting a weak stringer.

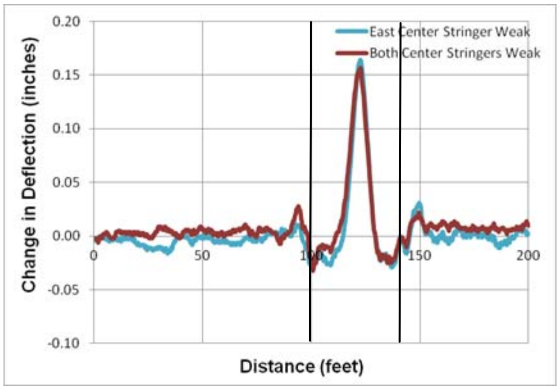

Figure 5. East Rail Difference in Deflection Response Measured by TLV under 40,000 lb per Wheel TLV Bogie Load Compared to Normal Condition

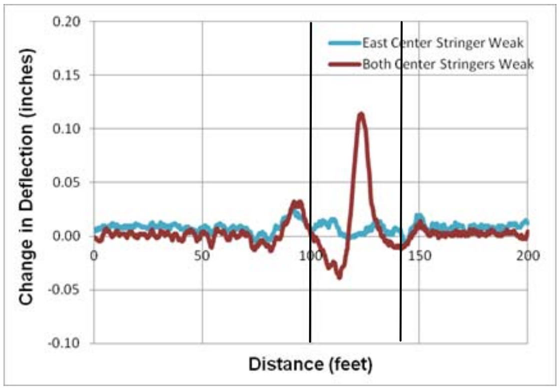

Figure 6. West Rail Difference in Deflection Response Measured by TLV under 40,000 lb per Wheel TLV Bogie Load Compared to Normal Condition

Detection of Bridge Defects with Track Geometry System

Track geometry data was collected for the same three test conditions on the BDTF. Figures 7 and 8 show the rail surface measurements for the east and west rails, respectively. The space curve data is shown, as opposed to any of the several chord-based measurements. The surface data clearly shows the location of the test bridge and the low approaches. Although not tested in this phase, it is expected that the track geometry data will also be effective in showing geometric defects in a bridge, such as a low pier, or a pier that is settling unevenly to one side.

In these figures, there are some visible differences between the normal condition and the two weak stringer conditions. These are not as clear as was noted above for the measurements under the TLV load bogie.

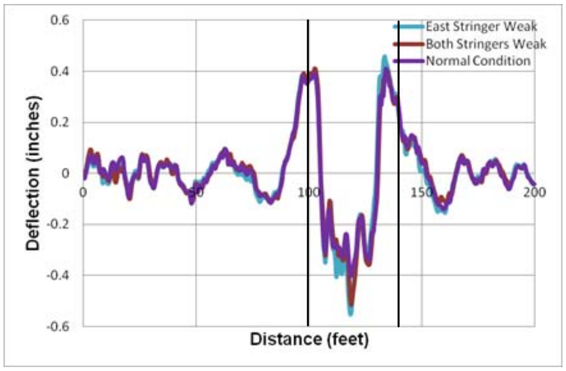

Figure 7. East Rail Surface Measured by Track Geometry System

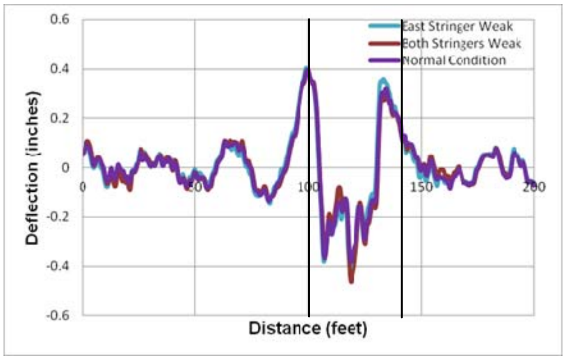

Figure 8. West Rail Surface Measured by Track Geometry System

Figures 9 and 10 show the differences in rail surface between the weak stringer cases and the normal condition, for east and west rails, respectively. There is some indication of the weakened stringers, but the signal-to-noise ratio is much less than what was observed under the TLV load bogie.

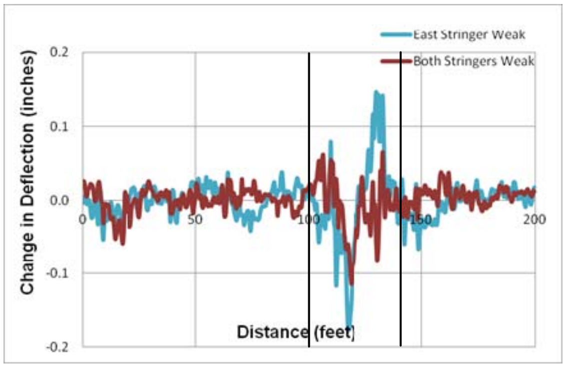

Figure 9. East Rail Change in Surface Measured by Track Geometry System

In summary, the track geometry data provides a good indication of low bridge approaches and a slight indication of a weakened stringer. The deflection measurement under the TLV load bogie with 40,000-pound wheel loads provides a strong indication of weakened stringers. This demonstrates that it is indeed possible to detect some bridge deficiencies using vehicle-based detection systems. Both deflection measurements under load, as well as some track geometry parameters, appear to be valuable components of an onboard bridge impairment detection system.

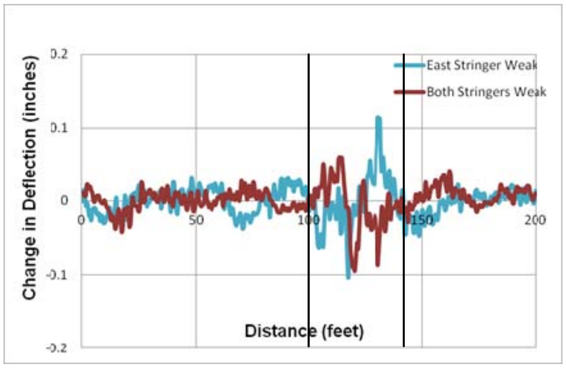

Figure 10. West Rail Change in Surface Measured by Track Geometry System

Future Work

Future research in this area will include the use of accelerometer-based systems including an instrumented locomotive and IFC. Use of accelerometer-based systems is particularly attractive as there are currently a number of these systems (locomotive VTI) currently operating on North American Class 1 railroads. It is likely that acceleration measurements will need more processing, filtering, and analysis in order to identify bridge defects.[2] Previous testing on BNSF indicated that it is not as easy to identify bridge characteristics with accelerometer-based measurements as it is with TLV and track geometry data. Testing of an alternative measurement of deflection under load might also prove valuable.[3] It may provide a similar strong signal for weak stringers.

Development of a vehicle-based bridge impairment detection system should at some point consider software and methods to establish and record baseline and periodic measurements to determine changes and rates of change. Some track geometry systems already have this capability, so it might be a simple expansion to add bridge-condition parameters.

Acknowledgements

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