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Bridge Condition Evaluation Using Three Track Geometry Cars

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Summary

Transportation Technology Center, Inc. (TTCI) is investigating the feasibility of using vehicle-based (onboard) systems to detect bridge impairments. A single onboard system offers the potential to assist with the inspection of numerous railroad bridges, as opposed to a structural health monitoring system that is captive to a single structure. This series of tests focused on detecting weak stringers and pier elevation changes in a trestle bridge using onboard systems. The testing was performed at the Bridge Deflection Test Facility (BDTF) at the Transportation Technology Center (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.

Pilot testing using the Track Loading Vehicle's (TLV) load system and track geometry system was performed in 2012.[1] In 2014, another set of tests was performed with a track modulus measuring system (MRail) and track geometry on FRA's DOTX 218 (also called T-18) car, track geometry on a passenger car, an accelerometer-equipped instrumented freight car, and a track modulus system (MRail) on a hopper car.[2,3]

In 2015, track geometry systems on the T-18 car, DOTX 220 (also called the T-20) car, and BNSF Car 80 were examined. Testing indicates the following preliminary conclusions:

- All three geometry systems are capable of detecting changes in pier elevations.
- Track geometry data from the T-18 and T-20 cars can detect changes in span stiffness condition accurately.
- Track geometry data on the BNSF Car 80 is able to identify weak approaches of the bridge. The results are less useful to distinguish weak spans from base bridge condition.
- For all systems, historical data from past runs is required for comparison. For lines with many spans of the same construction, outliers might be flagged in lieu of historical comparison.

This work was performed as part of the Association of American Railroads' Strategic Research Initiative on Bridge Life Extension.

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INTRODUCTION AND MOTIVATION

In 2015, TTCI tested three onboard track geometry systems at the Bridge Deflection Test Facility (BDTF) at TTC as part of an effort to provide better indication of bridges in need of maintenance or more detailed inspection. The results indicate that some of the onboard systems tested can be used successfully for bridge impairment detection.

The motivations for developing onboard inspection technology are twofold. 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 numerous bridges, as opposed to a structural health monitoring system that is fixed and capable of monitoring only a single bridge.

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 *Technology Digest* is on detecting weak bridge stringers and changes in pier elevations in trestle bridges.

Previous Studies

In 2012, TTCI performed tests with several onboard systems at the BDTF which was constructed to provide adjustable bridge strength and geometry conditions.[1] Three vehicles with onboard measurement systems were operated over the BDTF to determine their feasibility for use in onboard bridge condition assessment. The data was gathered using an instrumented locomotive (VTI), an instrumented freight car (IFC), a Track Loading Vehicle (TLV), and a track geometry system (mounted on TLV).

The VTI and IFC measurements were primarily acceleration-based measurements. The TLV used vertical loading to provide measurements related to track deflection and stiffness under various loads. The track geometry data provided 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-kip wheel loads clearly and correctly identified weak bridge stringers. The rail surface measurement from the track geometry system was able to identify low bridge approaches and changes in track surface over a bridge. Deflection measurements under load, as well as some track geometry parameters, appear to be valuable components of an onboard bridge impairment detection system.

Another set of tests was performed in 2014.[2,3] Several new systems were examined: track modulus measuring system (MRail) and track geometry on T-18, track geometry on a lightweight passenger car, an accelerometer-equipped IFC, and a track modulus system (MRail) on a hopper car. Testing indicated that all three types of systems (geometry, deflection, acceleration-based) are capable of detecting changes in pier elevations. Track geometry data from the T-18 car detected changes in bridge condition accurately. Track geometry data on the lightweight passenger car was able to identify poor approach geometry at the ends of the bridge. The results were less useful to distinguish weak spans from the base bridge condition.

For all systems, historical data from past runs is required for comparison. For lines with many bridge spans of the same construction, outliers might be flagged in lieu of historical comparison.

Test Conditions on the BDTF

The BDTF is a 42-foot, 3-span, T-rail trestle. It can be configured to provide variable pier geometries as well as variable stringer stiffness in all three spans. The BDTF is located on a lightly used section of track, so it is not subjected to high levels of degradation as might be experienced at the Facility for Accelerated Service Testing (FAST).

Test runs were made at speeds of 10 mph, 25 mph, 40 mph, and 45 mph to evaluate the effects of speed on the measurement.

BDTF configurations during the test included the following:

1. Base case—all spans and piers in normal “full strength” condition
2. Weak stringer in one side of center span
3. Weak stringers in both sides of center span
4. Weak stringers in one side of two spans (exterior and center) and abutment elevation raised
5. Weak stringer in one side of center span and on opposite side of exterior span and abutment elevation raised.
6. Base case—all spans and piers in normal “full strength” condition

More details about the configurations with appropriate drawing can be found in the previous research study (TD-15-006 and TD-15-007).[2,3]

Testing on BDTF with T-18 and T20

In August 2015, TTCI tested two FRA track geometry cars: T-18 and T-20 on the BDTF. Figure 1 shows the train during the test.

Figure 1. Testing on BDTF with T-18 and T-20 Vehicles

The T-18 test vehicle is a self-propelled state-of-the-art vehicle that conducts performance-based testing of railroad track strength. The total car weight is 175 kips and the average axle load is 43.8 kips. It is equipped with a track geometry measurement system to measure gage, alignment and track surface. In addition, the car is equipped with an MRail system to measure vertical rail deflection. T-18 utilizes a differential global positioning system (GPS) to provide high accuracy GPS coordinates to each foot surveyed.

The T-20 test vehicle is equipped with a track geometry measurement system to measure gage, alignment and track surface; a vehicle track interaction (VTI) system to measure truck and carbody accelerations in g's; and a differential GPS to provide high accuracy GPS coordinates to each foot surveyed.

Track geometry data was collected for the same six test conditions on the BDTF. The rail surface space curve measurements taken on T-18 for the east (left) and west (right) rails are shown in Figures 2 and 3, respectively. Also rail surface space curve measurements taken on T-20 are shown in Figures 4 and 5. The surface data from both cars shows the location of the test bridge and the low approaches.

Figures 2 to 5 also show the differences between the deflection measurements for weak stringers and for stringers in normal condition by using space curve data. In these figures, there are visible differences between the normal condition and the two weak stringer conditions as well as the raised abutment elevation. Relative deflections presented on the plots emphasize the weak stringers among different bridge conditions.

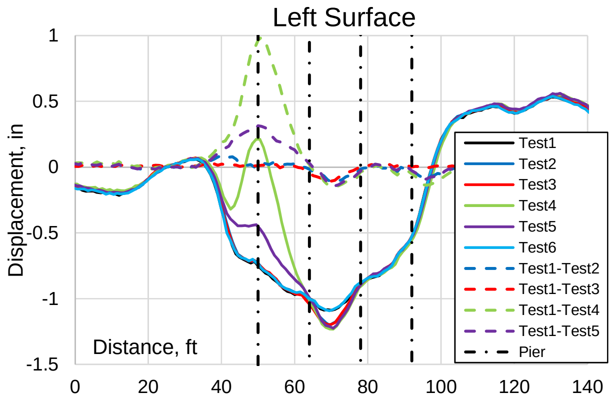

Figure 2. Left Rail Surface Space Curve, T-18

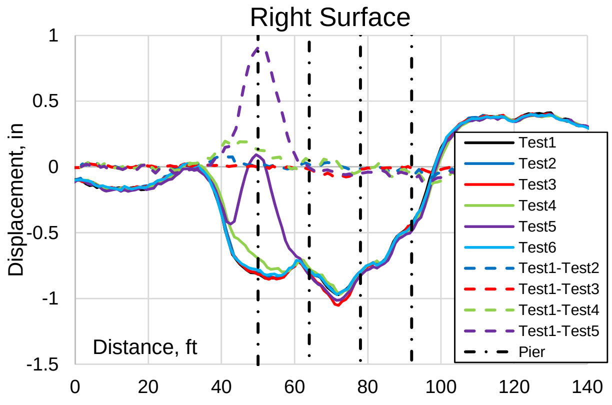

Figure 3. Right Rail Surface Space Curve, T-18

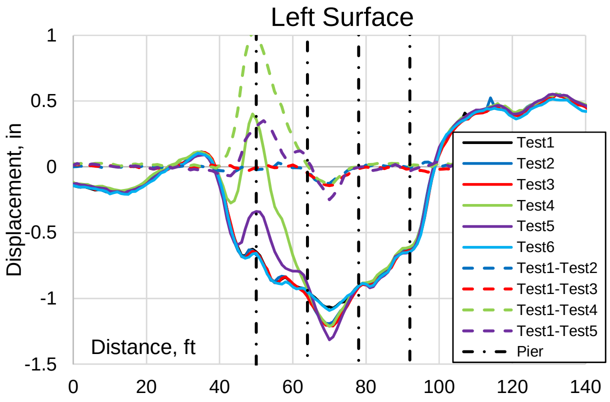

Figure 4. Left Rail Surface Space Curve, T-20

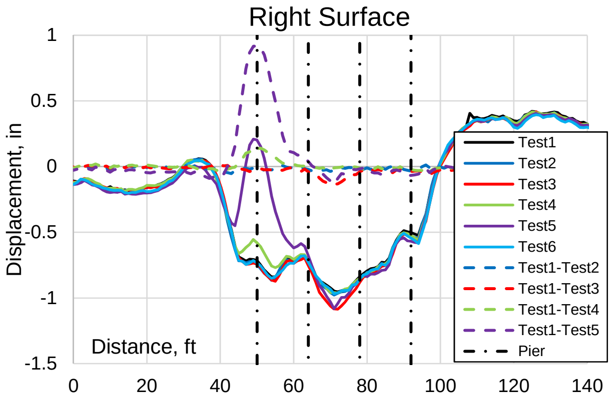

Figure 5. Right Rail Surface Space Curve, T-20

The results also show the difference between east (left) and west (right) side of the rail. These sets of data provide a good indicator for detecting a weak stringer.

Testing on BDTF with Track Geometry System on BNSF car

Track geometry data was collected with the BNSF Car 80 for the six test conditions on the BDTF. BNSF Car 80 is a converted railroad passenger car equipped with the instruments, measuring devices, and computers necessary to calculate track geometry. The total car weight is 166 kips and the average axle load is 41.5 kips. The Inertial Measurement Package, mounted in the center of the laser/camera beam, consists of a mounting structure, two fiber optic gyroscopes that measure roll and yaw rates, two accelerometers that measure vertical and lateral accelerations, and a signal conditioning board. Figure 6 shows BNSF Car 80 on the BDTF.

Figure 6. BNSF Car 80 Testing on the BDTF

The 62-foot chord measurements for the left and right rails are shown in Figures 7 and 8, respectively. The surface data shows the location of the test bridge and the low approaches. The track geometry data also effectively shows geometric defects in a bridge's supports, such as uplift of one side of the pier. This can be useful for detecting a pier that is settling unevenly to one side or has settled uniformly. However, the weak stringer conditions are not visible in these figures.

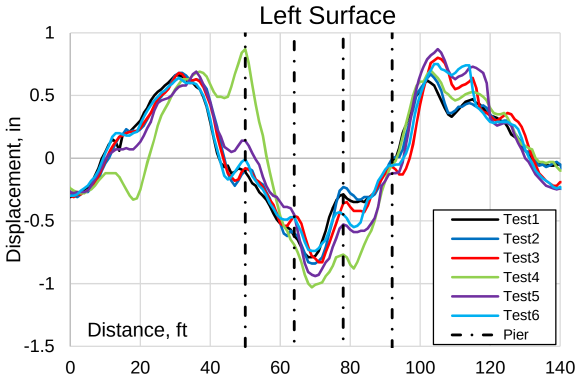

Figure 7. 62-foot Chord Left Rail Surface, BNSF Car 80

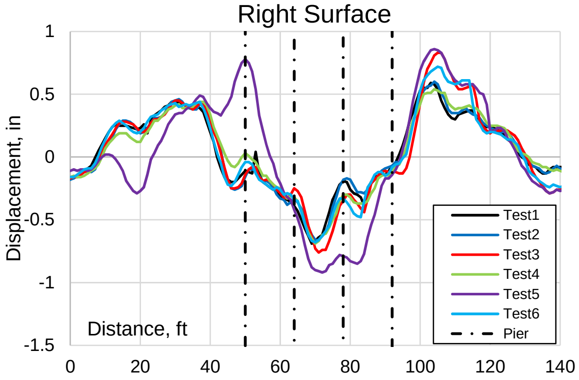

Figure 8. 62-foot Chord Right Rail Surface, BNSF Car 80

From track geometry data from BNSF Car 80, it is possible to detect that the approaches of the bridge were weak and the abutment was elevated 1 inch for Tests 4 and 5.

At a distance of 70 feet (the center of the bridge), the deflection under load is higher for the cases of a weak center span (both stringers, Test 3) and a weak stringer (east (left) rail only, Test 2), as compared to the deflection with all stringers in normal condition. The cases with the weakened stringers can be identified. However, the difference between peaks is less than 0.05 inch and it is not as prominent as it was for the measurements under the T-18 and T-20 cars. The string potentiometers installed on the spans recorded about 0.1 inch difference in deflection between various bridge conditions.

SUMMARY

Several onboard track geometry systems were tested in 2015. The results show that some of the systems can be used successfully for bridge impairment detection. The findings from the new test results are as follows:

- All three onboard track geometry systems are capable of detecting changes in pier elevations.
- Track geometry data from T-18 and T-20 cars accurately detects changes in span stiffness condition.
- Track geometry data from BNSF Car 80 identifies weak approaches of the bridge. The results are less useful to distinguish weak spans from the base bridge condition.

Trending of historical readings are likely needed to track changes in bridge condition and to predict when action might be required.

FUTURE WORK

Future work is recommended to evaluate additional track geometry cars and other onboard track evaluation systems on the BDTF at TTC that can operate in revenue service. Next steps in this research should be focused on developing reliable procedures for processing the data. For implementation, railroads would need to establish databases for their bridges and then begin establishing baselines for the onboard data. Accurate location of bridge ends is essential, possibly including on-the-ground location indicators in addition to GPS. New data would be compared to historical data to look for changes in the track geometry to infer trends in bridge condition. Appropriate trending software would need to be developed.

Acknowledgements

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3. Rakoczy, Anna and Duane Otter. "Bridge Condition Evaluation Using Track Geometry Systems." *Technology Digest* TD-15-007 AAR/TTCI, Pueblo, Colorado. March 2015.