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Bridge Condition Evaluation Using Track Geometry Systems

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Summary

Transportation Technology Center, Inc. (TTCI) 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 fixed to a single structure. The focus of this series of tests is on detecting weak stringers and pier elevation changes in a trestle bridge. The testing was performed at the Bridge Deflection Test Facility (BDTF) at the Transportation Technology Center, 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 Bridge Life Extension.

Pilot testing at TTCI using the Track Loading Vehicle's load system and track geometry system was performed in 2012.¹ In 2014, several new systems were examined: track modulus measuring system (MRail) and track geometry on Federal Railroad Administration's DOTX 218 (also called T-18) test vehicle, track geometry on a passenger car, an accelerometer-equipped instrumented freight car, and a track modulus system (MRail) on a hopper car. This *Technology Digest* (TD) presents the results of testing with the track geometry systems. Testing indicates the following preliminary conclusions:

- All three types of systems (geometry, deflection, acceleration-based) are capable of detecting changes in pier elevations.
- Track geometry data from T-18 detected changes in bridge condition accurately.
- Track geometry data on the lighter weight passenger car identified weak approaches of the bridge. The results were less useful to distinguish weak spans from base bridge conditions, perhaps due in part to its lighter axle loads.
- 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.

Further results about testing of the other systems can be found in companion TDs.^{2,3,4}



INTRODUCTION AND MOTIVATION

In an effort to provide better indication of bridges in need of maintenance or more detailed inspection, TTCI has been investigating the potential for using onboard technology to detect bridge impairment or changes in bridge behavior. The motivations for developing such a 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 hundreds 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. Various onboard methods have been proposed to measure bridge response. This study investigated the potential use of existing onboard systems to detect bridge defects or significant changes in track support conditions provided by a bridge. The study focused on a common railroad bridge type, the short span trestle. Short span trestle bridges built with steel, concrete, or timber spans are common railway bridges in North America. The research focused 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 Bridge Deflection Test Facility (BDTF), which was constructed to provide adjustable bridge strength and geometry conditions.¹ In 2014, 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 the following systems:

- Instrumented locomotive
- Instrumented freight car
- Track Loading Vehicle (TLV)
- Track geometry system (mounted on TLV)

The instrumented locomotive and instrumented freight car measurements were primarily acceleration-based measurements, which have proven valuable in finding relatively short wavelength defects, especially related to rail surface conditions. These systems are relatively low cost, rugged, and have the potential to provide high availability and wide coverage. The TLV used vertical loading to provide measurements related to track deflection and stiffness under various loads. The TLV track geometry system provided the measurements of track surface, alignment, cross level, gage, and related parameters.

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 by the TLV under a center bogie load of 40 kips per wheel clearly and correctly identified weak bridge stringers. Test results demonstrate it is possible to detect some bridge deficiencies using vehicle-based detection systems. The rail surface measurement from the track geometry system is 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.

New Testing on the BDTF at TTC

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.

The three test vehicles ran each of the BDTF test configurations at 10, 25, 40, and 45 mph (a total of 24 runs) to evaluate the effects of speed on the measurements. The six BDTF test configurations 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

Figure 1 shows the BDTF test configurations; weak stringers are red and elevated abutments are orange.

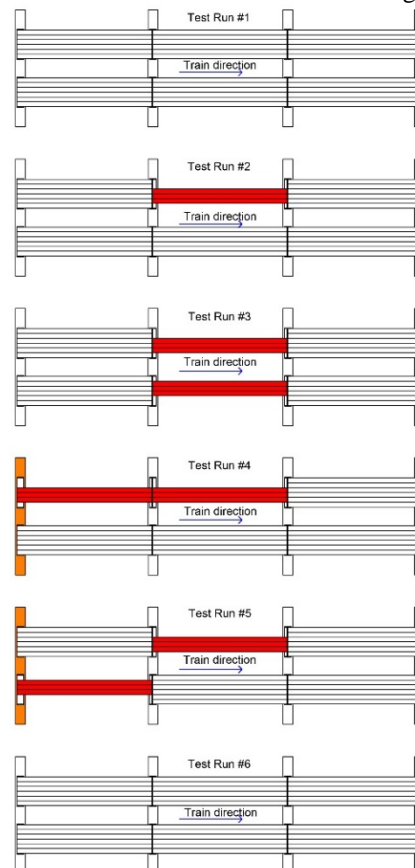


Figure 1. Illustrations of BDTF Test Conditions

Testing on BDTF with T-18

Federal Railroad Administration’s (FRA) 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 uses a differential global positional system (GPS) to provide high accuracy GPS coordinates to each foot surveyed. Figure 2 shows the T-18 passing over the BDTF. T-18 has also a Gage Restraint Measurement System that was not deployed during this testing.



Figure 2. T-18 Testing on BDTF

MRail measurements and results are presented in TD-15-006.⁴

T-18 is also equipped with a track geometry measurement system. It 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.

Using the T-18, track geometry data was collected for the first three test conditions on the BDTF. The rail surface space curve measurements for the left and right rails are shown in Figures 3 and 4, respectively. The surface data shows the location of the test bridge and the low approaches.

In these figures, there are visible differences between the normal condition and the two weak stringer conditions. Relative deflections presented on the plots emphasize the weak stringers between different bridge conditions. The results also show clearly the difference between the left and right sides of the rail.

Figures 5 and 6, the left and right rails respectively, show the differences between the deflection measurements for weak stringers and for stringers in normal condition by using a 31-foot chord measurement. In each rail, the presence of the weak stringers are clearly and correctly identified using the measurements data. These sets of track geometry data provide a good indicator for detecting a weak stringer.

Testing on BDTF with Track Geometry System on the Passenger Car

Track geometry data was collected with the passenger car for the six test conditions on the BDTF (Figure 1). The 13-foot

chord measurements for the left and right rails are shown in Figures 7 and 8, respectively.

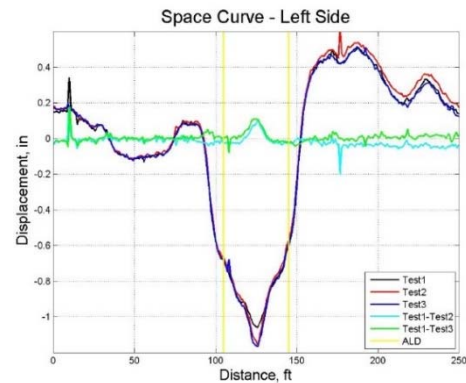


Figure 3. Left Rail Surface Space Curve, T-18

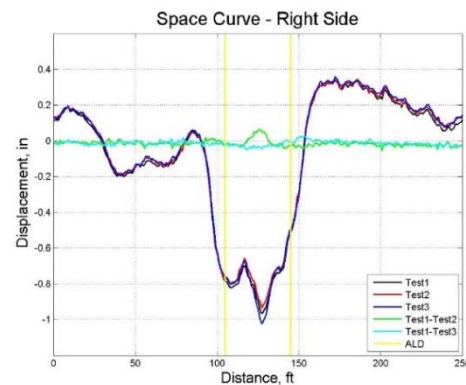


Figure 4. Right Rail Surface Space Curve, T-18

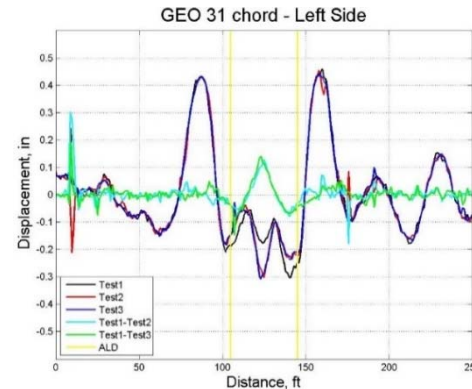


Figure 5. 31-foot Chord Left Rail Surface, T-18

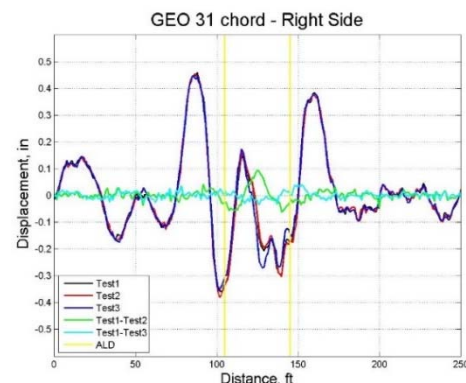


Figure 6. 31-foot Chord Right Rail Surface, T-18

The surface data clearly 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 the uplift of one side of a pier. This can be useful for detecting a pier that is settling unevenly to one side or has settled uniformly.

In these figures, there are some visible differences between the normal condition and the two weak stringer conditions, but these differences are not as clear as was noted above for the track geometry from T-18. However, the passenger car weighs 95 kips, or about half as much as the T-18 car, and it has a 23.75 kip axle load.

Based on track geometry data from the passenger car, it is possible to detect BDTF Conditions 4 and 5 in which the approaches of the bridge were weak and the abutment was elevated 1 inch.

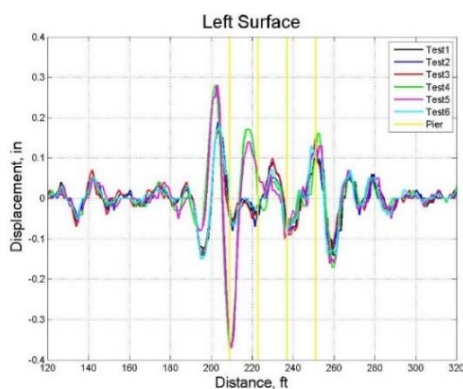


Figure 7. 13-foot Chord Left Rail Surface, Passenger Car

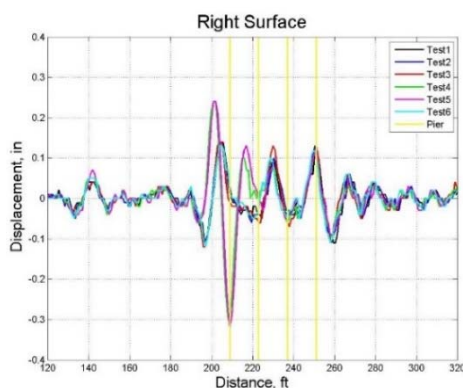


Figure 8. 13-foot Chord Right Rail Surface, Passenger Car

At distance of 230 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 (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 using the T-18 car.

Summary and Future Work

Several onboard systems were tested in 2012 and 2014. The results show that some of the systems can be used successfully for bridge impairment detection.

The findings from all the test results are as follows:

- TLV—clearly and correctly identified bridge conditions.
- Track geometry cars—some work better than the others, further investigation is recommended. The weight and axle spacing are likely to be contributing factors in the geometry data. The lightweight passenger coach deflected the weak stringers about half as much as did the heavier T-18 car.
- Instrumented freight car—provides useful results for bridge conditions evaluation; showing promise but is very sensitive to postprocessing.³
- MRail—systems correctly identified weak stringers. This system has the biggest potential to be used in unmanned revenue service at this point.
- All three types of systems (geometry, deflection, acceleration-based) are capable of detecting changes in pier elevations.
- Trending of historical readings are likely needed to track changes and predict when action might be required.

TUVX 001 equipped with an MRail system and the instrumented freight car can run unattended in revenue service trains. The accelerometer-based measurements on the instrumented freight car show promising results of use in revenue service, but the system is sensitive to the post-processing algorithm. Future work should be focused on developing reliable procedures for processing the data.³

Future work might also include evaluating additional track geometry cars and other track evaluation vehicles on the BDTF at TTC. If successful, revenue service trials should follow. For implementation, railroads would need to establish databases for their bridges and then begin establishing baselines for the onboard data. New data would be compared to historical data to look for changes in the track geometry to infer trends in bridge condition.

Acknowledgements

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References

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