TECHNOLOGY DIGEST

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Prototype Technique for Automated Lateral Track Panel-Strength Measurement

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Summary

Transportation Technology Center, Inc., has developed a prototype technique that uses the Track Loading Vehicle (TLV) to make automated measurements of lateral track-panel strength. This technique has been used successfully to identify weak spots continuously along the track, and to examine the effects of track-maintenance practices on track strength at the interface of the tie and ballast. Tests have been conducted on tracks at the Federal Railroad Administration's (FRA) Transportation Technology Center, as well as on revenue tracks. The work was jointly funded by the Association of American Railroads and the FRA.

Further refinement and full applications of this technique will enable railroads to identify and maintain weak spots to prevent potential track buckling and panel shifting. Applications of this technique will also enable railroads to quantify reduction in track strength due to maintenance and repair practices that disturb the tie-to-ballast interface, as well as strength restoration induced by dynamic ballast stabilization and/or traffic consolidation. This information can be used to optimize slow-order policies implemented following track maintenance or repairs.

This prototype TLV technique involves in-motion application of vertical and lateral loads to the track and measurements of unloaded and loaded lateral track profiles. To reveal strength variation along the track, the lateral axle load applied by the TLV load bogie should be between 14 and 18 kips with a vertical axle load of 20 kips. A lateral axle load of 18 kips was found to be most suitable. The TLV test speeds have been between 5 and 10 mph. Both unloaded and loaded track profiles are determined based on two offset measurements obtained by means of two sets of non-contacting laser/camera arrays. The accuracy of measurements is 0.01 inch, which is sufficient to cover the common range from 0.02 to 0.2 inch of total lateral deflection generated by the TLV test loads. A track is considered strong with a deflection of 0.04 inch or less, and weak with a deflection more than 0.1 inch (under 18-kip lateral axle load and 20-kip vertical axle load). However, more revenue track tests are needed to establish thresholds dividing strong and weak tracks. A weaker track shows not only higher average deflections, but also higher variations along the track.

Suggested Distribution:

- ❑ Maintenance of Way
- ❑ Planning & Analysis
- ❑ Track Maintenance
- ❑ R&T Department

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads

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INTRODUCTION AND CONCLUSIONS

As part of an overall effort to automate track-strength inspection methods, Transportation Technology Center, Inc., a subsidiary of the Association of American Railroads (AAR), has developed a prototype technique for automated measurements of track panel strength at the tie-to-ballast interface, using AAR's Track Loading Vehicle (TLV). This technique has been shown to successfully identify weak spots along the track and examine the effects of track-maintenance practices on track strength.

Sufficient lateral track strength at the tie-ballast interface is essential to safe train operation. With low track strength, track misalignment may grow under vehicle loads. A misaligned track with low strength may buckle under high compressive rail forces, or may shift excessively due to high lateral vehicle loads. To plan and implement early prevention of track buckling and excessive panel shifting, "automated inspection techniques" are needed to locate weak spots on revenue tracks. These techniques also are important to optimize track-maintenance practices. For example, any track maintenance and repairs that disturb the tie-ballast interface will reduce track strength greatly, thus requiring a subsequent speed restriction (slow order). Measurements of track strength variations due to track maintenance and repairs, dynamic ballast stabilization, and traffic consolidation will allow optimization of slow-order policies.

The prototype TLV measurement technique involves in-motion application of vertical and lateral loads to the track, and measurements of unloaded and loaded lateral track profiles. To reveal strength variation along the track, the applied lateral axle load should be between 14 and 18 kips, with a vertical axle load of 20 kips. The TLV test speeds have been between 5 and 10 mph, but can be increased up to 20 mph, as long as the TLV test loads remain constant (i.e., no significant dynamic load variations). Both unloaded and loaded track profiles are determined based on two offset measurements obtained through two non-contacting laser/camera arrays. A track is considered strong with a deflection of 0.04 inch or less, and weak with a deflection more than 0.1 inch (under 18-kip lateral axle load and 20-kip vertical axle load). However, more revenue track tests are needed to establish thresholds dividing strong and weak tracks. A weaker track shows not only higher average deflections, but also higher variations.

DEVELOPMENT OF THE TECHNIQUE

The development of this prototype technique is a result of three phases of research. The first two phases of research demonstrated the feasibility of continuously measuring track strength using the TLV. The technique, referred to as track-stiffness profile (or deflection-profile) testing, measures — while the TLV travels at a given speed — the small lateral deflections in the track that result from constant lateral and vertical loads. The concept was developed to measure both unloaded and loaded lateral track profiles by means of offsets. Although the earlier phases of research proved the concept, the measurement method was not suitable for revenue track testing, due to difficulties in testing through discontinuities such as joints, crossings, and sharp curves. In addition, the TLV required two passes to make the measurements.

The objective of the third phase of research was to improve the method for offset measurements so that the technique can be applied to revenue tracks. To do so, non-contacting laser/camera measurement systems were used in place of the rail-contacting deflection transducers. Two reference frames using identical laser positions were mounted to the front TLV truck and the center-load bogie, thus avoiding the two-pass requirement. These frame positions also reduced the problems caused by a large offset to the car-body reference while traveling in a curve. Exhibit 1 shows the new offset measurement systems. As illustrated, offset A gives initial or unloaded lateral track profile, whereas offset B gives loaded lateral track profile. A synchronized subtraction of offset A from offset B is thus the lateral track deflection due to the TLV test loads.

As discovered from the checkout tests, these two laser arrays have a measurement accuracy of 0.01 inch, which is sufficient for measuring unloaded and loaded lateral track profiles. The common range of the lateral deflection generated under the TLV test loads, which is smaller than both offsets A and B, is between 0.02 to 0.2 inch.

TEST RESULTS AND DISCUSSIONS

Extensive tests were conducted to check and validate this technique on test tracks at TTC as well as on revenue tracks. In this section, test results are given to show the validity and applicability of this prototype TLV technique.

As illustrated in Exhibit 1, offset B includes initial track misalignment (or unloaded profile) which is subtracted out by offset A. Check-out tests without applying lateral axle load were conducted to examine if both offsets measure the same profiles. Exhibit 2 gives a comparison of the offset A and offset B measurements at a speed of 20 mph. As shown, without an external lateral load, offset A was consistent with offset B for this 500-foot test zone. Therefore, during tests with an applied lateral axle load, the difference between offsets B and A should reflect the lateral track deflection due to the constant lateral test load.

Check-out tests were also performed to compare the offsets measured via the laser/camera arrays with the wayside lateral tie deflections. Note that the offset measurements are taken from the non-flanged rail (opposite to the pushed rail), which moves laterally approximately the same as the ties (TD97-005). Exhibit 3 shows comparisons of wayside and onboard test results. As can be seen, the onboard laser/camera arrays measured similar results to the tie deflections measured from the wayside transducers. These comparisons also indicate that the "reference length" is such that offset differences between B and A are similar to the actual track deflections.

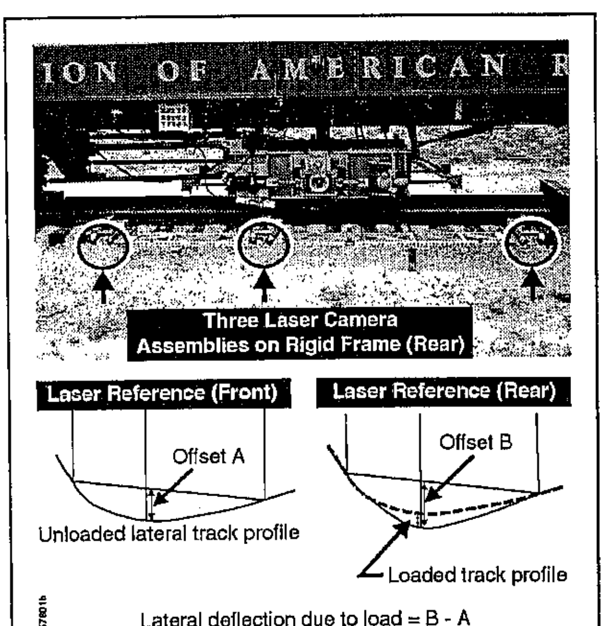

Exhibit 1. Offset Measurements

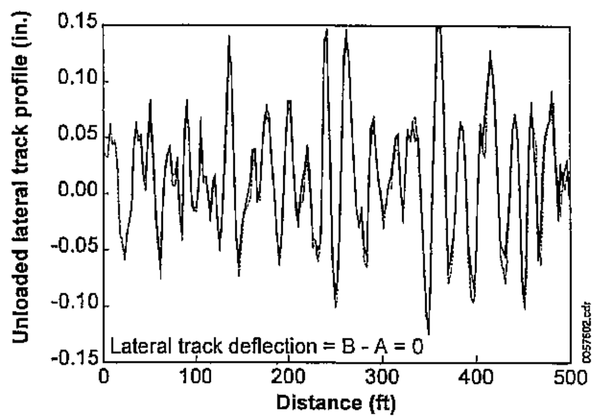

Exhibit 2. Comparison of Offset A and Offset B Measurements at 20 MPH

Tests were conducted on tracks at TTC to examine how well this technique can detect weak spots. To create weak spots on a test track, consecutive ties in several zones were pulled laterally and then pushed back using a speed swing machine. Exhibit 4a gives an example of in-motion test results from a 350-foot test zone. Two weak areas were created in this test zone. As shown, the automated technique easily revealed the two weak areas, which showed much higher deflections than the rest of the test track. To confirm these in-motion test results, three stationary TLV load-versus-deflection tests were also conducted

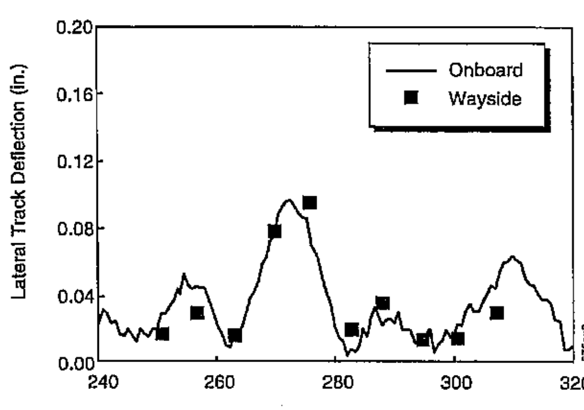

Exhibit 3. Comparison of Wayside and Onboard Test Results

at selected locations: one corresponding to strong track, the other two corresponding to weak spots. As shown in Exhibit 4b, the stationary test results were consistent with the in-motion test results. That is, locations D and E showed lower strength than location C.

This automated TLV technique for strength measurement was recently applied to Norfolk Southern (NS) railroad tracks. Test results and major conclusions for this NS test will be published in a separate document. During this revenue track testing, continuous measurements of track strengths were conducted at 5 to 8 mph through various track features including left- and right-hand curves, road crossings, turnouts, and bridges. The technique detected weak zones along the track and also quantified the effects of various maintenance practices on track strength. Exhibit 5 gives an example of deflection profiles (under 18-kip lateral and 20-kip vertical axle loads) collected over a track length of roughly 1,200 feet. The first 400 feet (600 to 1,000 feet) of this test zone was tamped only, while the final 800 feet (1,000 to 1,800 feet) was tamped and stabilized using a dynamic ballast stabilizer. As shown, the non-stabilized track showed higher deflections (or lower strengths) than the stabilized track (0.08-inch average deflection for the non-stabilized track versus 0.03-inch average deflection for the stabilized track).

With further improvements to the laser/camera measurement systems, and more field demonstrations to provide a better understanding of test results, this TLV prototype technique can be implemented as an automated in-motion strength-inspection method.

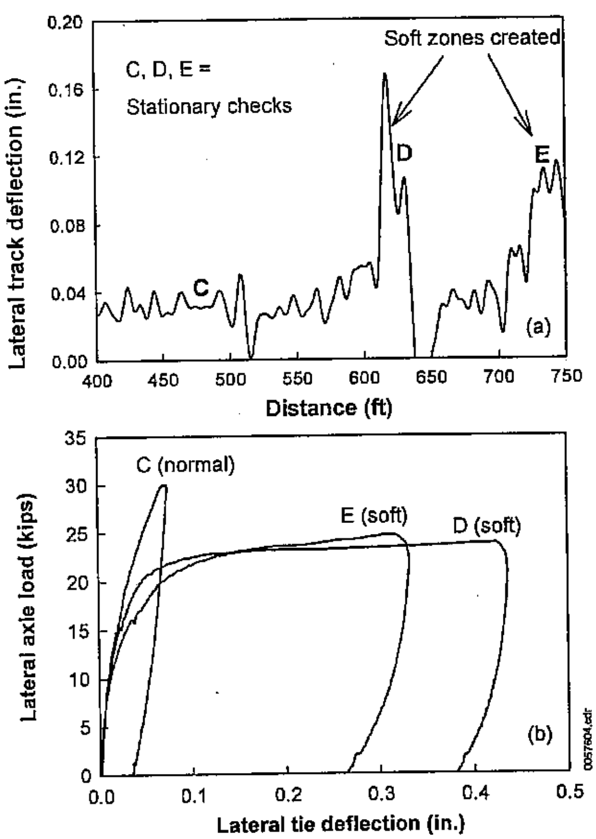

Exhibit 4. In-Motion and Stationary Test Results

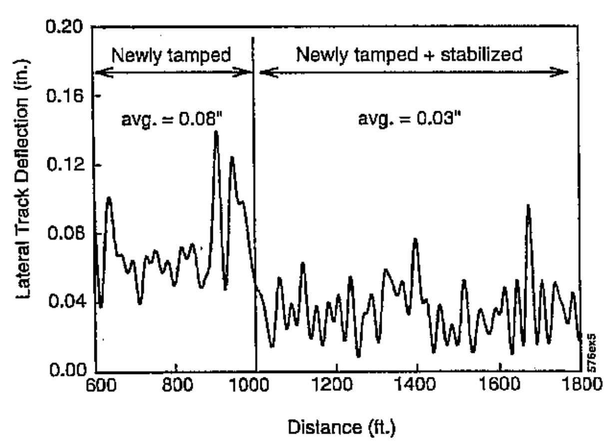

Exhibit 5. Deflection Profiles over Revenue Track

Note: Contact Dingqing Li at (719) 584-0740 with questions or comments about this document.

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A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON D.C., 20001