TECHNOLOGY DIGEST

Timely Technology Transfer — 99-007

TRACK VERTICAL STRENGTH MEASUREMENT USING TTCI'S TRACK LOADING VEHICLE

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Summary

Engineers at the Transportation Technology Center, Inc., (TTCI) have been developing a method of measuring vertical track stiffness using TTCI's Track Loading Vehicle (TLV). These tests were funded by the Association of American Railroads (AAR) to better understand origins of non-uniform vertical track stiffness.

At present, there are no quick methods for determining whether poor ballast conditions or poor subgrade are causing a weakness in vertical track support, therefore railroads often may attempt to fix a soft spot by tamping the problem area, when the real problem lies within the subgrade level. The objective of the test being developed at TTCI is to provide a means of locating the source of poor track support with a continuous in-motion, non-destructive manner. The long-term goal of this testing is to test revenue track at approximately 10 mph, marking areas of poor track support and indicating whether ballast or subgrade should be maintained.

As part of this development, a system of measuring vertical track deflection under various axle loads has been implemented on a consist containing the TLV, an empty tank car, and an instrumentation coach. This system has proven itself to be a repeatable means of measuring track deflection variations on tangent level track. At present, the data must be analyzed after the test has been conducted to determine where track instabilities exist, and the probable source of any weaknesses. A real-time computer algorithm is under development to process load deflection data and indicate when track modulus has exceeded a given threshold. The algorithm will also predict whether the problem is at the subgrade or the ballast level.

Suggested Distribution:
- ☐ Maintenance of Way
- ☐ Planning & Analysis
- ☐ Track Maintenance
- ☐ Safety

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

INTRODUCTION AND CONCLUSIONS

This project has been undertaken to improve railroad maintenance procedures as they relate to vertical track strength. Poor vertical track support is known to stem from poor quality and insufficient ballast, weak subgrade, or both. Inadequate substructure support is corrected by rebuilding the subgrade. A weak ballast condition is most often addressed by tamping. The result of prescribing the wrong treatment for low strength track is expensive and can lead to unnecessary slow orders. The goal of this project is to measure track vertical support with an in-motion, non-destructive test, and to diagnose the causes of track instabilities so that suitable remedial actions can be pursued.

The technique is based on the ability to compare variations in track vertical deflections under two different vertical forces. The lower force level is used to estimate seating stiffness, which is defined as the track's resistance to displacement when subjected to no external load (as compared to the seating wheel load of 14 kips). A 14-kip wheel load was determined to be the load required to close the voids/gaps between the rail/tie/ballast interface. Large variations in the track deflections under 14 kips (and hence in seating stiffness) tend to indicate a problem in the ballast area.

Subsequent application of a 31-kip wheel load yields contact stiffness, which is defined as the track's resistance to displacement when increasing from the seating load (14 kips) to the larger contact load (31 kips). Gaps between the rail/tie/ballast interface have already been closed with the 14-kip seating load, therefore significant additional deflection is assumed to be taking place at the subgrade level. Large variations in this contact stiffness can indicate a problem with the substructure.

Full load deflection is defined as the sum of seating and contact deflections. Using these definitions, the non-linear hardening characteristic of the track is idealized as a bi-linear (two-slope) system, as shown in Exhibit 3.

In 1998, a system for measuring vertical track deflection was built and tested on track located at the Federal Railroad Administration's Transportation Technology Center. The system has shown to be repeatable in measuring track deflections over a speed range of 5-15 mph. In a comparison between static deflection testing and in-motion testing on tangent track, the system performed well. However, to date, the system has not been proven in superelevated curves, and force control diminishes at speeds greater than 15 mph.

Test validation has been conducted over slab concrete, asphalt road crossing, and typical ballasted track conditions. The magnitudes of contact and seating deflections were shown to decrease over sections known to be very stiff. The system has not yet been tested over track sections of historic rapid degradation.

INSTRUMENTATION DEVELOPMENT

The TLV and a tank car were instrumented with displacement sensors (LVDTs) to acquire vertical deflections of the railhead relative to the car bodies. All LVDTs were mounted rigidly to the associated car body, and measured the vertical deflections at the center of several wheel sets, which acted as rail followers. Five sets of auxiliary idler wheel sets were installed to provide the needed reference rail-height measurements. Exhibit 1 depicts the locations of displacement transducers as mounted on auxiliary wheel sets under the tank car. During testing, the auxiliary wheel sets ride on the track with 500 pounds of force applied through a pneumatic system. Using chordal-offset methods, the distance measurements from the car bodies to these auxiliary wheels account for the (otherwise moving) reference frames provided by the car bodies.

All of the auxiliary wheel sets are attached to four bar linkages in order to retain correct

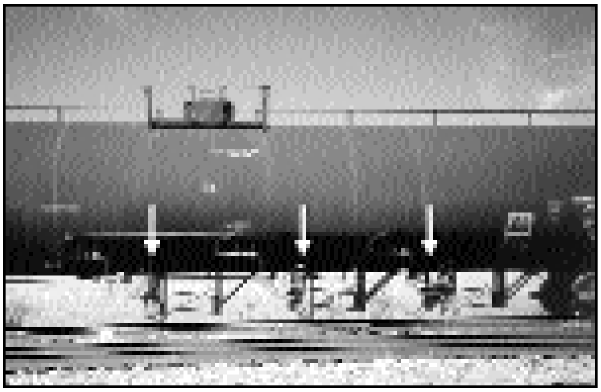

Exhibit 1. Locations of Displacement Transducers in Tank-Car Instrumentation

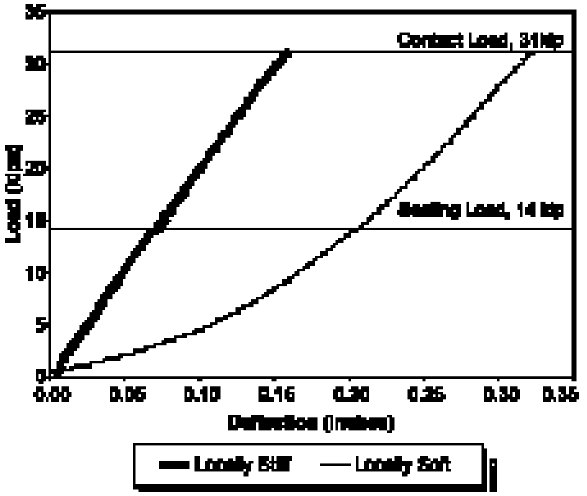

Exhibit 2. Stationary TLV Results from Two Vertical Push Tests

orientation. Five of the eight LVDTs are located at the auxiliary wheel sets, in addition, two transducers are located at the leading trucks of the tank car and the TLV, and one LVDT is located at the TLV center test axle.

The empty tank car pulled behind the TLV is primarily used to account for existing (no-load or very low load) vertical profile variations in the track. This is because the 31-kip wheel loads under the TLV end trucks are sufficient to create a basin which prohibits an existing profile measurement from being taken within the length of the TLV. The weight of the empty tank car exerts only a 14-kip load at the end trucks, creating a smaller basin and allowing for a no-load vertical profile measurement.

PRELIMINARY TLV STATIONARY TESTS

Exhibit 2 shows the force versus track deflection for a test conducted near a road crossing at TTC. This figure compares a locally stiff portion of track to a laterally softer section as gathered from results of TLV stationary push tests. The softer section shows significant hardening as load increases, indicating that ballast maintenance may be useful. Unfortunately, such stationary testing is time consuming and limited to discrete locations.

IN-MOTION TEST DESCRIPTION AND DATA ANALYSIS

In the TTCI track tests, the TLV Tank Car measuring system was pulled as a consist behind the AAR-100 instrumentation coach. Train speeds ranged from 5 to 15 mph. Test routes were defined using automated location detectors for special track work and landmarks (road crossings, bridges, etc.). Data collected during testing included the eight deflections, the TLV forces and speeds, and the location sensor output.

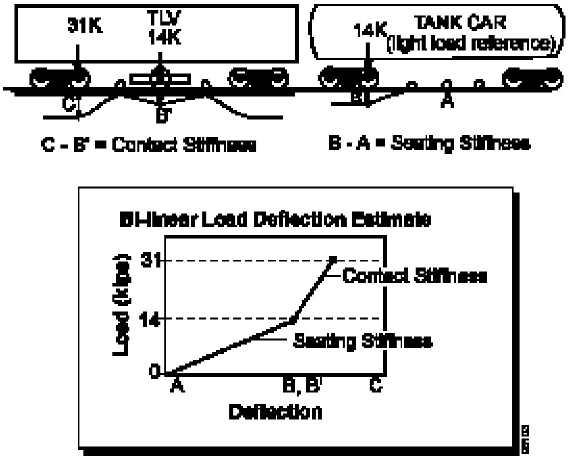

Exhibit 3. Test Load versus Deflection Nomenclature

The data from the eight LVDT channels measuring track deflection were manipulated in a computer algorithm to compute seating (0-14 kip), contact (14-31 kip), and full-load (0-31 kip) deflections. This algorithm accounts for spatial shifts between the TLV basins and the tank-car measurements (64 feet to the rear). Also, measurements from the auxiliary wheel sets reduce the effects of car-body motion.

Large variations in seating stiffness (or deflections) indicate a poor ballast condition, while large variations in contact stiffness point to a weak subgrade. This nomenclature is depicted in Exhibit 3.

To examine in-motion results over various track surfaces, basin measurements were recorded as the TLV exited the concrete floor of the Central Services Building at TTC, across an asphalt parking area, and into the CSB yard. Exhibit 4 shows the computed seating deflections over this portion of track. Deflections were found to be similar for the asphalt and the ballasted sections. However, it is clear that the seating deflections computed over the concrete area were near zero, as would be

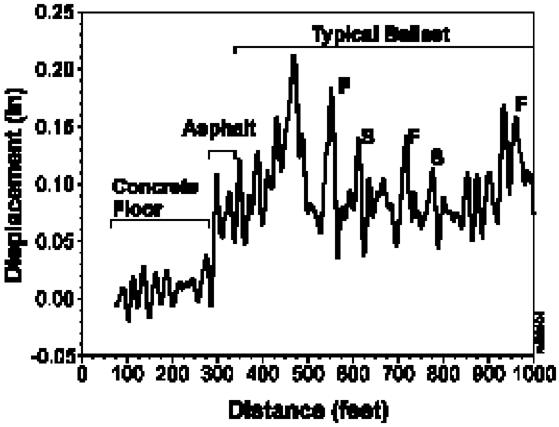

Exhibit 4. Seating Deflection over Various Subgrade Conditions

expected for such a stiff structure. Again, the seating deflection is the difference between the track profile under no external load, as compared to the track basin with a 14-kip load. Several of the higher deflection values in the ballasted track are associated with pumping at or near frogs and switches (labeled "F" and "S" respectively).

To show that the in-motion measurements are repeatable, tests were performed over a section of track on different days at different speeds. During the tests, contact loads (31 kips) and seating loads (14 kips) were kept constant, while no-load, seating, and contact deflections were recorded. Results have been quite repeatable as shown by Exhibit 5 which plots contact deflections measured at three test speeds, ranging from 5 to 15 mph.

IMPLICATIONS

This project has thus far shown the ability to simultaneously measure seating and contact deflections. Several factors currently limit the effectiveness of the TLV test system including:

- On very soft track, basins can become large enough to affect auxiliary idler wheel (reference) deflection measurements.
- Track curvature and superelevation may affect stiffness computations by skewing mid-axle deflection measurements.

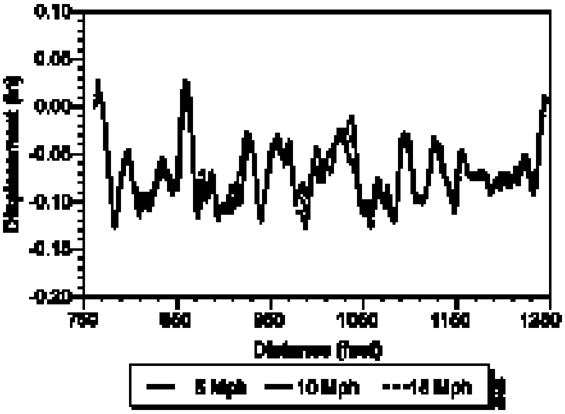

Exhibit 5. Contact Deflection Repeatability

These effects will be quantified during 1999 testing. Also to be tested during 1999 is the optimization of seating and contact loads, which are currently defined at 14 kips and 31 kips respectively.

Tests will be conducted at the TTC facility where weaknesses in subgrade and ballast areas can be defined. In addition, trials will be conducted on revenue track when regions of historical vertical profile degradation can be accessed.

REFERENCES

1 Chrismer, S., and Shust, W., "In Motion Vertical Track Stiffness Measurements with the Track Loading Vehicle," Transportation Technology Center Inc., Technology Digest No. 98-005, Association of American Railroads, February, 1998.

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A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. Box 79780, BALTIMORE, MD, 21279-0780.