TECHNOLOGY DIGEST

Timely Technology Transfer

"IN-MOTION MEASUREMENTS OF LATERAL TRACK STRENGTH AT TIE-BALLAST INTERFACE"

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TD 97-005

Summary
Recent research conducted by the Association of American Railroads (AAR), Transportation Technology Center (TTC), Pueblo, Colorado, has shown the feasibility of automated inspection methods to effectively measure available lateral track strength at the tie-to-ballast interface.

Full development of such a method will lead to early identification and maintenance of weak spots before further track degradation and increased maintenance is needed. Application of such a method will also enable railroads to quantify relative strength differences between tracks in different stages of their maintenance cycles. This information can be used in conjunction with traffic requirements to effectively prioritize surfacing and lining maintenance activities.

The test technique involves in-motion application of vertical and lateral loads and measurement of the resulting track lateral deflection using the Track Loading Vehicle (TLV). Tests conducted at TTC showed that this test technique was capable of measuring lateral track strength variation along the track. The weaker spots in the test tracks exhibited consistently larger deflections than neighboring zones, under constant vertical and lateral loads.

The optimum lateral axle load appears to be 15 kips (at 14 kip vertical) or 18 kips (at 20 kip vertical) for detecting variations in strength along the track. The change in track deflection increases as a function of lateral load; therefore, increased displacements at the weak spots are easily identifiable using higher lateral axle loads. However, it was also shown that application of higher lateral axle loads can result in a sudden track shift in a weak section.

This *Technical Digest* is the second in a series of three (TDs 97-004 & 97-006) summarizing the AAR's investigation of lateral track strength (track panel shift) using the TLV. The project is jointly funded by the AAR and the Federal Railroad Administration.

Suggested Distribution:
- ❑ Maintenance of Way
- ❑ Track Maintenance
- ❑ R&T Dept.
- ❑ Safety Dept.

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INTRODUCTION AND CONCLUSIONS

A major problem in optimizing track maintenance practices is the inability to efficiently measure track strength and adjust maintenance policies based on the results. Improvements in this field should minimize total vehicle and track costs, by taking into account vehicle loads and dynamic performance. The annual cost of derailments due to track geometry alone is estimated to be about $20 million. Surfacing and heat related slow orders also cost railroads tens of millions of dollars in train delay costs. Therefore, given current and anticipated vehicle loads and performance, high priority is assigned to Association of American Railroads' (AAR) research for developing track performance-based maintenance guidelines, and automated track inspection tools designed to reduce system costs.

As part of an overall effort to develop automated track strength inspection methods, AAR has developed an in-motion stiffness profile test technique to measure variable lateral track strength and to detect weak locations. AAR's Track Loading Vehicle (TLV) was used to apply constant vertical and lateral panel shift loads while in motion, and to measure lateral track deflections as an indication of track strength variation. Tests conducted so far have led to the following preliminary conclusions:

- The stiffness profile test technique was capable of measuring track strength variation at the tie/ballast interface along the track. The weaker spots present in the test tracks exhibited larger deflections than neighboring zones, under constant vertical and lateral loads. For tests conducted on tracks at the AAR, Transportation Technology Center (TTC), repeatability of track strength measurements using the TLV has been satisfactory, and weak spots have been consistently identified.
- The variations of track strength shown by the stiffness profile testing were consistent with trends shown by limited wayside measurement results and Single Tie Push Test (STPT) results. The TLV stiffness profile tests can show lateral track strength variation within a longitudinal resolution of several feet.
- The optimum lateral axle load for detecting variation of lateral track strength, appears to be 15 and 18 kips, with a vertical axle load of 14 or 20 kips respectively. Larger lateral axle loads are better — giving more distinctive profiles corresponding to variable track strength — but may result in a sudden shift over weak track.

The eventual application of the measurement technique is expected to increase the efficiency of track maintenance. Since the TLV was designed as a research tool, its many and diverse capabilities hinder its application as a production track inspection tool. However, development of this approach to a track measuring system could produce an innovative track inspection vehicle.

TEST TECHNIQUE

Track stiffness profile (deflection profile) testing is designed to locate weak spots, as illustrated in Exhibit 1. The technique measures the small track lateral deflection resulting from constant lateral and vertical loads while the TLV travels at a given speed. If other conditions are similar throughout a section of track, then any location where the track deflects less will possess higher track strength. In other words, the soft spots in tracks will manifest themselves in the form of larger lateral track shifts on the deflection profile, as illustrated in Exhibit 1.

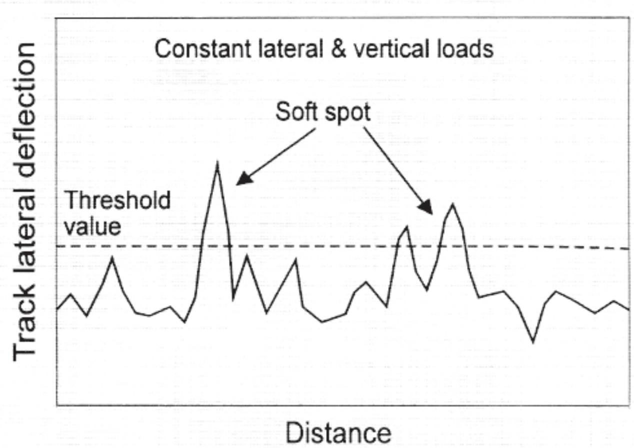

Exhibit 1. In-motion Stiffness Profile Testing

To illustrate this concept, a rail-contacting system was used for the lateral track deflection measurements. Deflection transducers were installed at the TLV load bogie, and lateral track deflections were measured as lateral displacements of the non-flanged rail, which moves approximately the same as the ties due to panel shift loads (i.e., negligible rail to tie lateral movement). The reference frame for the onboard measurements, as shown in Exhibit 2, hangs from the TLV car body. Inevitably, however, this reference moves with the car body as it reacts to the applied track panel shift loads. To quantify the reference movement, two deflection transducers were installed at the TLV ends to measure the movements of the car body with respect to the rail. As found from other tests under this project, the rail under the TLV ends is unaffected by the TLV panel shift loads. Thus, the rail under the TLV ends was used as a separate reference to quantify the car body movement.

Exhibit 2. TLV and Reference Frame

With the current deflection measurement system, two passes of the TLV over the test zone are required to obtain the desired profile, as shown in Exhibit 1. The first run measures the initial track misalignment with zero lateral load. The second run is made over the same track section at a pre-defined lateral load to measure the sum of the initial misalignment and lateral track response.

Currently, the AAR is improving the existing measurement system to make it more suitable for revenue track testing. This new system will use two laser-camera systems to measure the initial track lateral alignment as well as the loaded track lateral profile simultaneously during one run. Furthermore, with a non-contact measurement system, the TLV test speed should increase by 10 mph above the current, but slow trials.

RESULTS

Initial in-motion lateral track strength tests were conducted on test tracks at TTC. All test sections consisted of tangent continuously welded rail. Detailed track information and test results will be published this year in an AAR research report. Typical examples of in-motion track strength test results follow.

Exhibit 3 shows the deflection profile obtained over the test track in Section 40 of the TTC High Tonnage Loop (HTL). Note that initially the track deflected consistently about 0.1 inch between 100 and 200 feet into the test zone. However, at a location from 270 to 470 feet, the deflection profile shows higher deflections, and therefore lower lateral track strength. In fact, the track located around 460 feet was so weak that it suddenly shifted during testing, causing an amplitude of 6 to 7 inches. Exhibit 4 shows the distorted track structure due to this sudden shift. Also, from 220 to 240 feet into the test zone, the deflection profile exhibits a sharp peak. Inspection of this zone after testing showed a small but visible shift in this region. This shift occurred as a result of a weaker ballast resistance at this location, and the stiffness profile test was able to identify this local change in track strength.

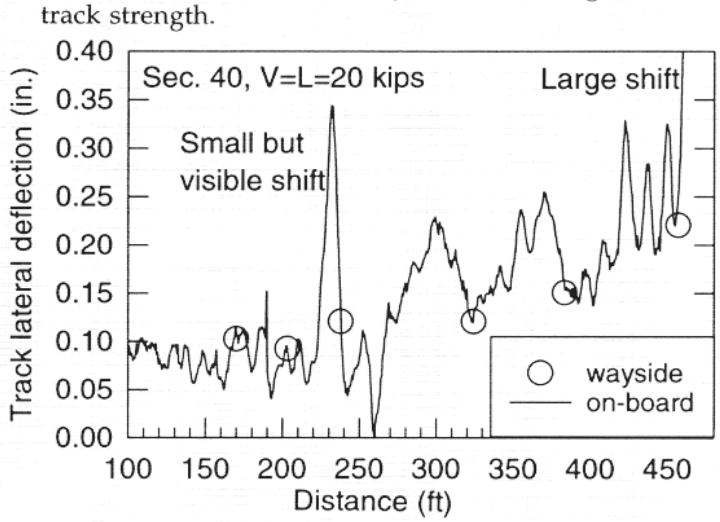

Exhibit 3. Stiffness Profile Test in Section 40

Exhibit 4. Large Shift during Stiffness Profile Test

The longitudinal trends of track strength as established using the TLV stiffness profile testing were also consistent with other results. Four STPT measurements (a static test measuring the lateral resistance of an unrestrained tie pushed through the ballast) within the test zone, as well as six wayside tie-to-ground deflections were compared to the onboard TLV profile. The STPT test results are given in Exhibit 5, and wayside deflection data are included in Exhibit 3. Both STPT testing and wayside deflection measurements indicated that the track tended to be weaker in the zone from 270 to 470 feet.

Exhibit 5. STPT Test Results

Distance (ft)	210	320	380	450
STPT Peak Resistance (lb)	2700	2000	1500	1400

Exhibits 6a and 6b show a comparison of several lateral track deflection profiles as produced using a range of lateral and vertical loads over a test segment located in HTL Section 33. These curves show that the resulting track deflections increase as a function of lateral load, and the response at the weaker spots (near 170 to 200 feet into the test zone) are easily identifiable at higher lateral loads.

The optimum lateral axle load to detect a weak zone appears to be 15 kips using a vertical axle load of 14 kips, and 18 kips under a vertical axle load of 20 kips. Future TTC and revenue track test results will refine this selection of optimum axle loads, and will identify deflection threshold levels for recording weak spots in track.

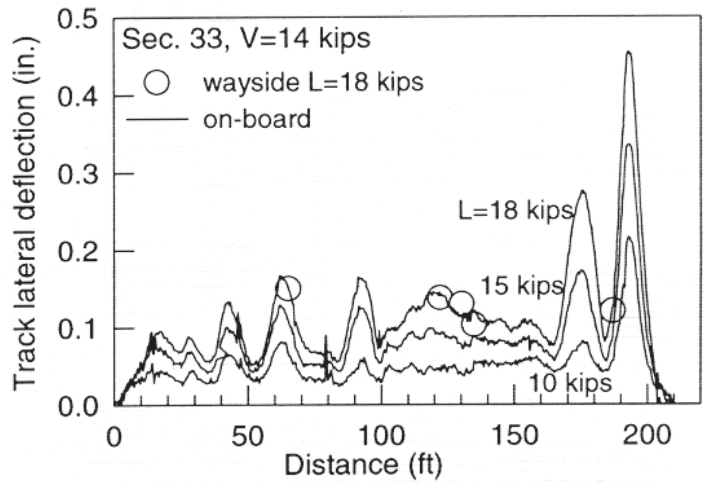

Exhibit 6a. Stiffness Profile Test in Section 33

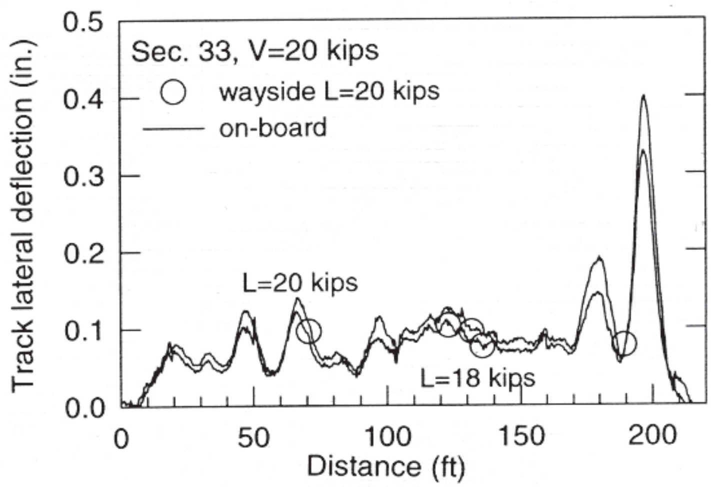

Exhibit 6b. Stiffness Profile Test in Section 33

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