TECHNOLOGY DIGEST

Timely Technology Transfer — 02-002

Automated Vertical Track Strength Testing Using TTCI's Track Loading Vehicle

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Summary

Extensive in-motion tests in revenue service have shown the Track Loading Vehicle (TLV) to be a viable vertical strength measurement tool. The TLV can locate weak track in both tangent and curved track. It can also distinguish between ballast and subgrade problems with a two-pass method, using 10- and 40-kip test loads, respectively.

For the past decade, the TLV has been used for many different research programs including gage-strength and lateral track panel strength testing. Presently the TLV has been configured to test track vertical strength to address the following:

- Large track stiffness variation along a track indicating weak track support or abrupt transitional stiffness change, which can lead to poor vehicle/track performance.
- Poor vertical track support because of low-quality ballast or weak subgrade.
- The need for track upgrades for higher operation speeds and/or heavier axle loads.

As part of an Association of American Railroads' Strategic Research Initiative Program, the Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado, adapted the TLV consist to measure vertical track deflections under various axle loads while in-motion. These measurements provide an automated means of testing vertical track strength and stiffness variation along a track, locating sources of poor track support, and evaluating the load carrying capacity of an existing track for possible upgrade to higher operation speeds and/or heavier axle loads.

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

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INTRODUCTION

The Track Loading Vehicle (TLV) is designed to perform extensive measurement and data collection tasks over a diverse range of applications. Typical applications have included testing track gage strength, bridge strength, longitudinal rail force, flange-climb derailments, and track panel shift strength. As part of an ongoing AAR research program, TTCI has adapted the TLV consist to measure vertical track deflections under various axle loads. These measurements provide a means of testing vertical track strength and stiffness in an in-motion and non-destructive manner. Extensive tests in revenue service have shown that the TLV is capable of picking out weak track locations during in-motion testing at approximately 10 mph, in both tangent and curved (no greater than 10.3°) track. The TLV can also distinguish between ballast problems and subgrade problems with a two-pass method, using 10- and 40-kip test loads, respectively.

The technique is based on the ability to measure variations in track vertical deflection under given vertical forces. Based on extensive testing at the Federal Railroad Administration's Transportation Technology Center, Pueblo, Colorado, and in revenue service, a method was developed to identify weak track locations that may need immediate maintenance. Upon exceeding a pre-determined threshold level, which may indicate low or marginal support, the track can be marked for follow-up investigation.

MEASUREMENT TECHNIQUE

The test-consist includes the TLV, an empty instrumented tank car, and the instrumentation coach. The TLV and the tank car are instrumented with laser displacement sensors to acquire vertical deflections of the railhead relative to two reference frames mounted to the vehicle bodies (see Exhibits 1 and 2). Loaded and unloaded vertical deflection profiles are determined by three chordal-offset measurements from each reference frame.

The loaded deflection profile is obtained under the TLV load bogie. During an in-motion test, the TLV applies a vertical force using the center load bogie. It is capable of applying a range of wheel loads anywhere from 1 to 60 kips. The standard TLV test wheel load is 40 kips.

The second measurement comes from the tank car trailing the TLV. The tank car is equipped with a center load bogie much like the TLV; however, this bogie is equipped with pneumatic actuators and is only capable of applying wheel loads of up to 3 kips (2 kips normally used). This load is used to assure wheel/rail contact at all times. The empty tank car is used to measure the existing vertical profile variations (unloaded profile). The empty tank car exerts only 14 kips at the end trucks, creating small deflection basins that have little effect on the vertical profile measured from the reference frame attached under the center of the car.

The data collection software overlays the loaded and unloaded profiles and calculates the difference to get the actual deflection of the track caused by the TLV test load. Note that displacement measurements are obtained only on the left side rail, facing the direction of travel.

Exhibit 1. TLV and Laser Reference Beam

Exhibit 2. Tank Car and Laser Reference Beam

TTCI = Transportation Technology Center, Inc.; AAR = Association of American Railroads

TEST RESULTS

In addition to test load and milepost information, during in-motion tests, the following three parameters are often given as the output of vertical strength tests:

1. Curvature Indicator - used to indicate where curves and tangents begin and end.
2. Track Deflection - the difference between loaded profile (obtained under the TLV test load) and unloaded profile (obtained under the empty tank). This is the parameter indicating characteristics of vertical track support and represents track response under the given test load. For a given test load (40 kips), higher deflection indicates weaker track and lower defection indicates stronger track. This is an offset-based measurement, and therefore is a relative measure of track deflection under the test load.
3. Vertical Strength Index - calculated from the "Track Deflection" channel. This channel is used to show the variation of vertical track support. A weaker track is generally more variable in vertical support along the track; thus, the values of this strength index will be higher for weaker track. Because this is an index showing track strength variation, measurements taken at bridge approaches, road crossing, and where subgrade support is weak may have higher values. The TLV also spray paints the track when this index exceeds a predetermined threshold.

Exhibit 3 is an example of the revenue service test results for these three parameters in terms of distance traveled. As illustrated, the locations A, B, and C showed higher magnitudes in both track deflection and vertical strength index, thus being identified as weak locations.

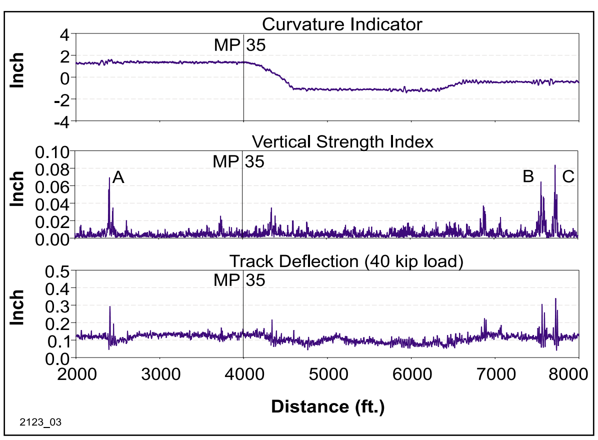

Exhibit 3. Example of In-Motion Track Strength

In a recent revenue service test, the TLV was used to find areas that required maintenance in the vertical realm. One test included approximately 50 miles of double track. Extensive test results were obtained for determining the weakest areas and for scrutinizing where the weaknesses lie. Exhibit 4 shows a comparison of deflection profiles between two track sections. One section is strong or stiff, whereas the other section is weak.

To validate the in-motion deflection profile results shown in Exhibit 4, a few static tests were conducted in these two sections. Exhibit 5 shows the static load-deflection results, corresponding to the two sections indicated in Exhibit 4. As illustrated, the weak section showed much lower track modulus (approximately 1,100 lbs/in./in.) than the stiff section (9,400 lbs/in./in. track modulus); i.e, the static track modulus test results were consistent with the in-motion track profile results.

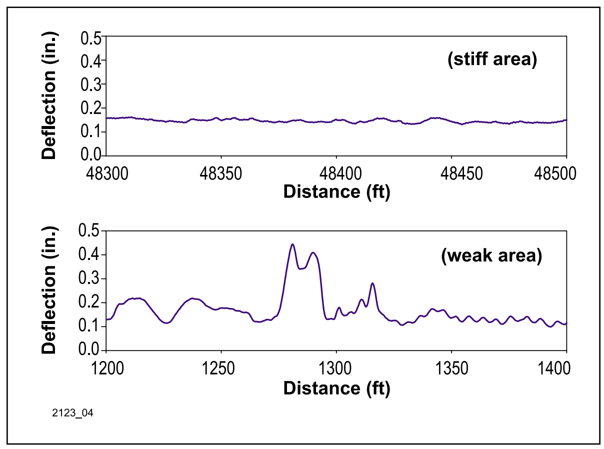

Exhibit 4. In-Motion Test Results Between Strong and Weak Tracks

To obtain a dynamic track modulus, which is calculated using the offset based measurement while in-motion, two runs are required at similar train speeds. The first run, under a 10-kip load, is used to remove track voids. The second run is under a 40-kip load. The two vertical deflection plots are then post-processed (alignment and subtraction) to provide a graph of the contact deflection. This result can be used to differentiate between soft subgrade and weak ballast conditions. Dynamic track modulus is also calculated from the contact deflection.

Exhibit 6 shows revenue service test results obtained over two separate runs at the same section with vertical loads of 10 and 40 kips, respectively. The results of contact deflection were obtained from calculating the difference between the results under 40 and

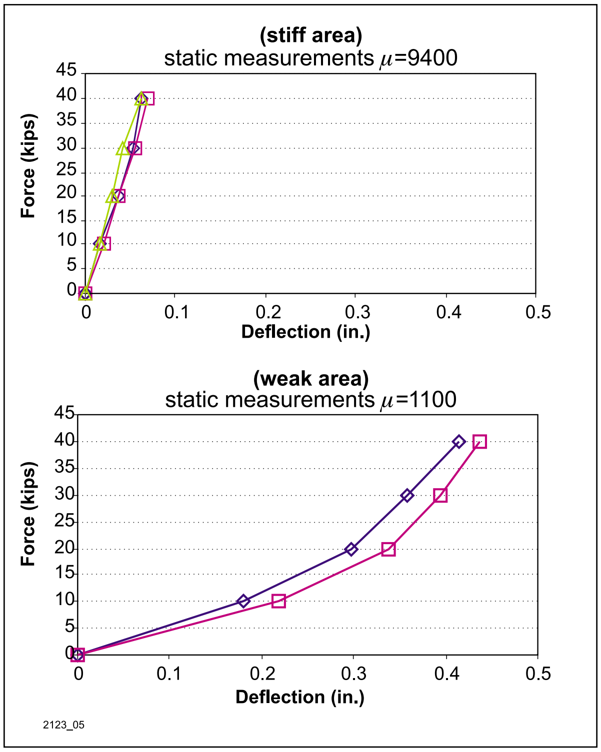

Exhibit 5. Static Test Results Between Strong and Weak Tracks

10 kips. Because the 40-kip results include deflections due from the entire track and subgrade, and the 10-kip results include deflections primarily from the rail, tie, and ballast, the contact deflection results (the difference) should reflect the subgrade support characteristics. Therefore, the stiffness variation of the track in this example was mostly due to ballast, as indicated by consistent contact deflection results. The exception is at 11,100 feet, where there is a large deflection due to weak subgrade. Dynamic track modulus, calculated from contact deflection, is also included in Exhibit 6. As shown, the weak spot at 11,000 feet has a dynamic track modulus below 1000 lbs/in/in.

Exhibit 7 shows an example of the test results in statistical format. Each data point represents a magnitude of the 95th percentile or 50th percentile for a quarter-mile segment. Those statistical values are used to show vertical strength variation over a long stretch of track (i.e., over 40 miles in this example) as Exhibit 7 illustrates.

Presently, TTCI continues to use the TLV for revenue service testing, along with testing on site. The TLV has been modified to perform both vertical and gage strength tests. These tests are concurrently being used to study the effects of track strength degradation over time and accumulated traffic.

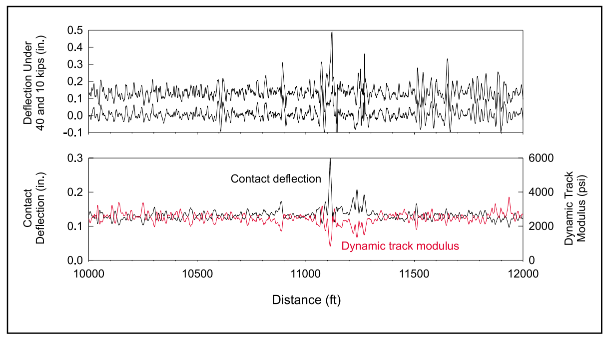

Exhibit 6. Two-Pass In-Motion Test Results

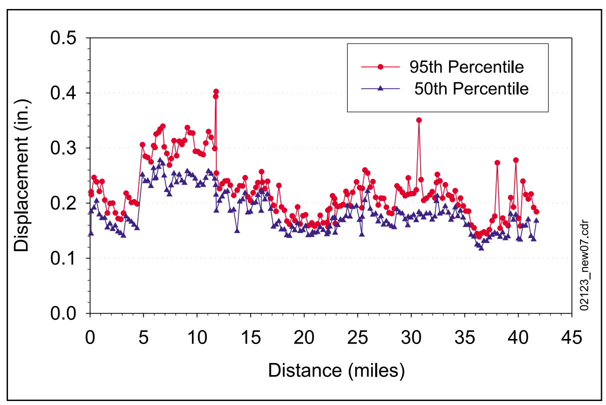

Exhibit 7. Statistical Distribution of Vertical Deflection Results in Quarter-mile Increments

Note: Please contact Randy Thompson at (719) 584-0753 with questions or comments about this document.
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