TECHNOLOGY DIGEST

Timely Technology Transfer

"EFFECTS OF LOAD AND TRACK VARIABLES ON LATERAL TRACK STRENGTH"

by Dingqing Li,
William Shust and Semih Kalay

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Summary

On-track tests of lateral strength (panel shift) using the Track Loading Vehicle (TLV) at the Association of American Railroads (AAR) Transportation Technology Center, Pueblo, Colorado, showed vertical axle load and ballast consolidation to be the most important factors affecting measured lateral track strength.

This report summarizes the results from controlled shifts of intact track using the TLV in a stationary test mode. Track surfacing was found to reduce ballast resistance considerably, requiring up to 9 million gross tons (MGT) of traffic to fully restore the pre-tamped strength.

The test program has improved the fundamental understanding of the tie/ballast interface, and examined relationships between track infrastructure, maintenance techniques, and lateral performance.

Ballast type had a less significant effect on lateral track strength. Use of concrete ties provided a moderate benefit in improving lateral track strength (5-20 percent) and in reducing strength variability along the track. A 125,000-pound temperature-induced rail longitudinal force change reduced the lateral track strength only slightly.

To date, TLV system demonstration and on-site examination of panel shift fundamentals have been completed. Pending results from a third phase off-site, the final results will be used to recommend optimal maintenance approaches while ensuring adequate lateral track strength, and to develop performance-based guidelines for improved slow order policies following track surfacing efforts.

Additional results from the in-motion TLV tests are discussed in two complementary *Technology Digests* (TDs 97-005 & 97-006), and may ultimately lead to another tool for performance-based track inspection, similar to loaded gage measurements. The ongoing study is jointly funded by 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

Sufficient lateral track strength is essential to maintain track stability under high longitudinal rail forces and/or vehicle loads. Track maintenance operations often significantly reduce lateral track resistance, and can increase the propensity for track buckling. Also, heavier axle loads and higher train speeds cause a growing influence of vehicle-induced forces on the track lateral stability. To address these concerns, extensive lateral track strength tests were conducted at the Association of American Railroads (AAR), Transportation Technology Center, Pueblo, Colorado. Significant conclusions are given below:

- Vertical axle load has a major effect on the resistance of a track panel to lateral deflection. Therefore, lateral track strength and stiffness should be defined for a given vertical axle load. Larger vertical axle loads result in increased lateral track strength; however, this effect has diminishing returns. Consequently, for a given lateral track deflection, the allowable lateral to vertical force ratio (L/V) will be lower with higher vertical axle loads.
- Lateral load-deflection relationships are nonlinear. Therefore, lateral track strength should be defined at specific deflection levels. Also, once a track panel is pushed past a critical deflection (e.g, 0.1 to 0.2 inch under a vertical axle load of 20 kips), the track will possess much lower lateral strength and stiffness.
- Ballast consolidation has a significant effect on lateral track strength. Ballast tamping reduced tie-ballast resistance considerably, and up to 9 MGT of traffic were required to restore the pre-tamped strength.
- Other variables tested had less influence on lateral track strength. The ballast type showed little effect on lateral track strength. Limited tests showed that use of concrete ties provided moderate benefit (5 to 20 percent) by improving lateral track strength defined at small lateral deflections. They also reduced variability of lateral strength along the track.
- Rail longitudinal forces had only minor effects on stationary strength measurements. A 125-kip change from tension to compression forces in the rails only slightly reduced lateral track strength (less than 10 percent).

These results were obtained in controlled lateral shifts using the Track Loading Vehicle (TLV) to apply forces to the rails via normal wheel profiles. The lateral track deflection is measured as tie deflection relative to the ballast.

TLV stationary tests can provide quantitative information on lateral track strength with a maximum panel push of 0.3 to 0.5 inch. In addition single tie push tests (STPT) were performed, and the effects as found were similar to TLV tests.

STRENGTH PARAMETERS

Exhibit 1 shows a typical lateral load-deflection curve resulting from a stationary test under a vertical axle load of 20 kips. As illustrated, the loading curve consists primarily of two regions with distinctively different slopes. In the first region, the track exhibits a much higher stiffness than after the lateral deflection reaches a certain magnitude. In the second region, however, the track has much lower stiffness. Beyond this transition, a small increase in lateral load will lead to a rapid increase in lateral track deflection.

In order to better compare these non-linear load-deflection relationships as influenced by different load and track variables, several stiffness and strength parameters were defined. For example, $k_{0.05}$ and $k_{0.1}$ were used to define the stiffness in the first region; $k_{0.2\text{-}0.3}$ is used to define the stiffness in the second region. Finally, the strength parameters (i.e., required lateral load to produce a certain amount of deflection) are designated as $L_{0.05}$, $L_{0.1}$, $L_{0.2}$ and $L_{0.3}$.

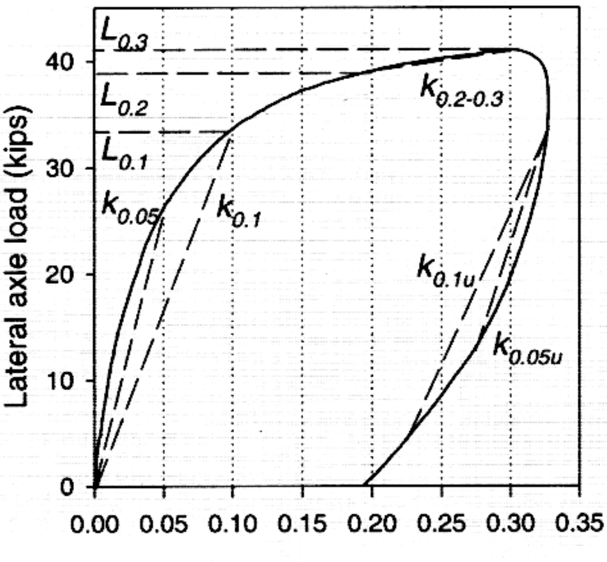

Exhibit 1. Stationary Load-Deflection Relationship

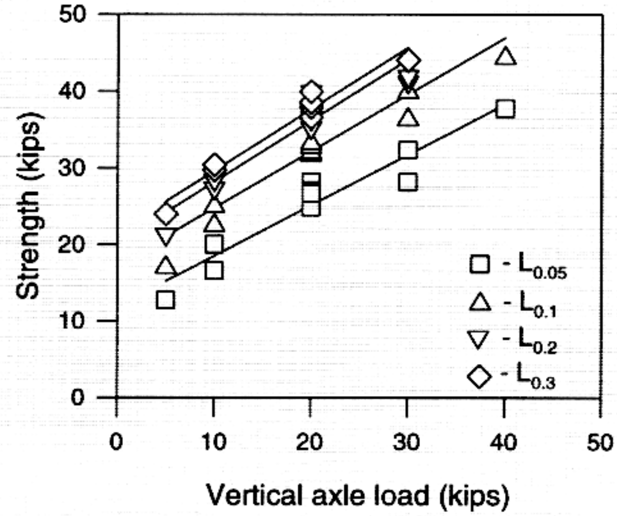

Exhibit 2. Correlation between Strength and Vertical Load

RESULTS AND ANALYSIS

Extensive test results and analyses will be published this year in a separate AAR research report. The following summarizes typical results showing the effects of various load and track variables on lateral track strength.

Exhibit 2 shows typical results of various vertical axle loads on lateral track strengths defined at different tie deflections. As illustrated, an increase in vertical axle load will lead to an increase in strength. The effect of vertical axle load, V, can be quantified by the following equation:

$$L_\delta = L_{\delta 0} + a_\delta V \qquad (1)$$

where L_δ = lateral track strength for a given deflection level, δ,

$L_{\delta 0}$, a_δ = intercept and slope (see Exhibit 3 for their values based on many tests).

By rearranging Equation 1, the following equation is obtained to determine the allowable axle L/V ratio for a given deflection:

$$\left(\frac{L}{V}\right)_{allowable\ at\ \delta} = a_\delta + \frac{L_{\delta 0}}{V} \qquad (2)$$

Exhibit 3: Summary of L_o and a Values

δ (in.)	$L_{\delta 0}$ (kips) average	$L_{\delta 0}$ (kips) range	a_δ (kip/kip) average	a_δ (kip/kip) range
0.05	13	10-16	0.47	0.32-0.66
0.1	15	13-17	0.69	0.54-0.79
0.2	21	18-20	0.64	0.42-0.80
0.3	22	-	0.80	-

In equation 2, $L_{\delta 0}$ and a_δ are constants dependent only upon the deflection level. Therefore, this equation indicates that as the applied vertical load increases, the allowable L/V ratio will become lower.

Exhibit 4 shows the effect of ballast consolidation under the track upon the lateral strength as determined from tests conducted on the High Tonnage Loop at TTC. As illustrated, a skin lift (0.5 inch) and ballast tamping operation reduced track strength considerably. The track strength loss required up to 9 MGT of traffic before complete recovery of pre-tamped strength.

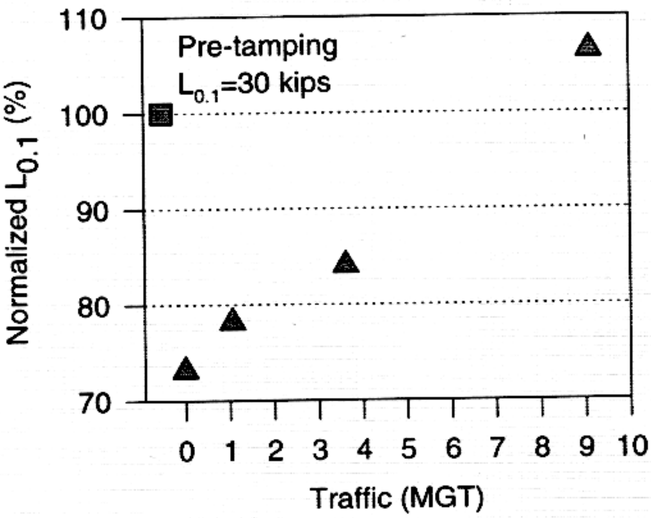

Exhibit 4. Effect on Normalized Track Strength of Ballast Consolidation under Traffic (each symbol represents an average of three TLV measurements)

Exhibit 5 shows the effects of longitudinal rail forces on measured lateral track strength determined from stationary TLV shifts. In this exhibit, the horizontal axis gives rail temperature change from its neutral temperature (which is directly proportional to rail longitudinal force). For the 50 degree F range of rail temperature change considered, a 125-kip change from tension to compression only slightly reduced the lateral track strength (less than 10 percent). Further work using a lower neutral temperature is planned.

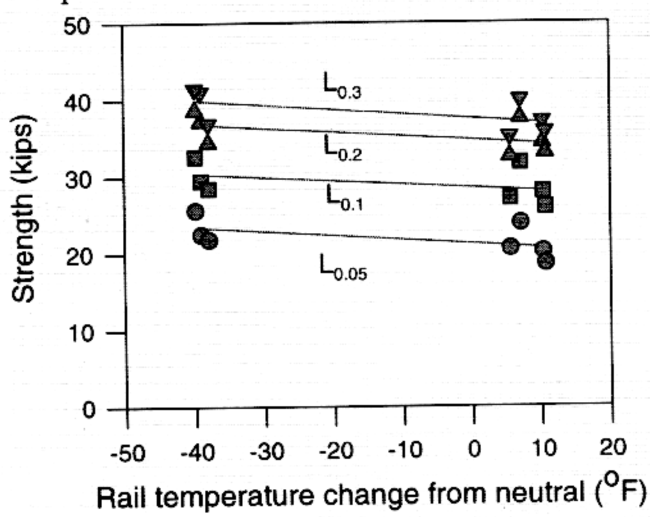

Exhibit 5. Effects of Rail Longitudinal Forces

However, the effect of longitudinal rail forces was more significant during in-motion tests, as discussed in TD 97-005. A similar temperature change resulted in larger cumulative plastic deformation (misalignment growth) under repeated passes of high lateral axle loads.

Lateral track strength determined using TLV stationary tests includes many factors, not only the components which contribute to STPT resistance (i.e., ballast resistance to pushing of a single tie free of rail restraints and under zero vertical load). For example, such influences as track panel lateral bending stiffness and tie-to-ballast friction affect TLV measurements, but not STPT tests.

Regardless, Exhibit 6 gives the correlations between the TLV lateral track strength parameters and the STPT peak resistance for one track infrastructure. The results were obtained during the ballast consolidation study, thus a wide range of track strength was available for correlating TLV and STPT test results. As illustrated, an increase in STPT peak resistance corresponds with an increase in lateral track strength determined from TLV stationary tests.

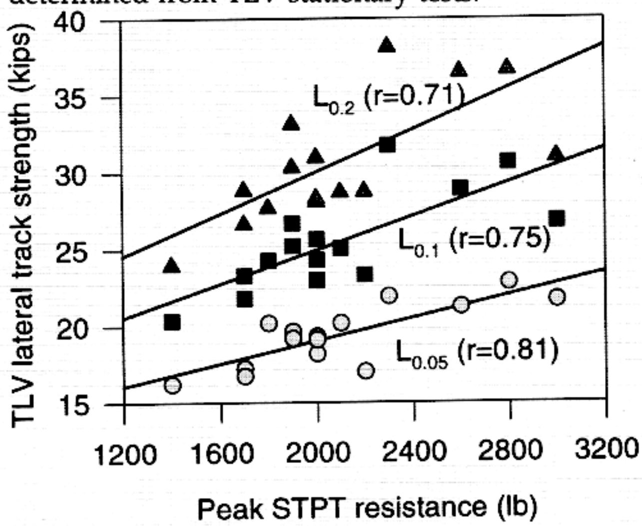

Exhibit 6. Correlation between TLV Lateral Track Strengths and STPT Peak Resistance

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

E-mail: dingqing_li@.aar.com

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