

"TRACK PANEL SHIFT DUE TO REPEATED PASSES OF LATERAL AXLE LOADS"

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Summary

The Association of American Railroads (AAR) has conducted a series of full-scale track panel shift tests using the Track Loading Vehicle (TLV) at the Transportation Technology Center, Pueblo, Colorado. Measurements under a variety of repeated vertical and lateral axle loads indicate there is a critical lateral load level at which track deformation increases rapidly with additional load passes.

These repeated passing tests show that at or near critical load levels, temperature-induced rail compressive forces may lead to accelerated growth of misalignments due to lateral loads. In addition, results show that concrete-tie track can sustain moderately larger force levels than track with wood cross-ties.

Track panel shift refers to the growth of residual lateral deformation (or misalignment growth) of the track panel over the ballast. Under adverse conditions, excessive and rapid track panel shift can affect the quality and safety of train operations.

These tests complement the stationary TLV examinations of lateral track strength and contribute to AAR's efforts to develop an effective lateral strength inspection method. Results from these tests over North American freight tracks will also be used to evaluate safety criteria originally developed by European railroads for preventing excessive track panel shifting.

This *Technology Digest* is the last in a series of three (TDs 97-004 & 97-005) summarizing the AAR's investigation of lateral track strength (track panel shift) using the TLV. Tests were jointly sponsored 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

Track panel shift is defined as the growth of residual lateral deformation of a track panel over the ballast; it is a lateral misalignment phenomenon primarily caused by repeated lateral axle loads. As railroads trend toward heavier axle loads and higher train speeds, vehicle-induced forces may lead to the loss of track lateral stability under unfavorable track conditions. The resulting misalignment, when combined with other adverse conditions, may also lead to track buckling.

The Association of American Railroads' track strength research program is currently focused on full-scale track panel shift tests and is co-funded by the Federal Railroad Administration. This digest discusses the repeated-passing technique applied using a variety of vertical and lateral axle loads (the sum of loads under both wheels), using the Track Loading Vehicle (TLV).

Measurements of track panel shifts due to repeated TLV load passes have led to the following conclusions:

- The accumulation rate of panel shift depends on the magnitudes of lateral and vertical axle loads. The critical lateral load increases with an increase in vertical axle load. An increase in vertical axle load also leads to a decrease in track misalignment growth. The critical lateral loads predicted by the existing Prud'homme criteria (described later) are conservative compared to the results obtained from TLV tests.
- Sudden and large panel shifts (up to 6 inches laterally) were observed on several occasions. They occurred at TLV test axle lateral to vertical force (L/V) ratios near or equal to 1.0 during controlled in-motion tests. Such excessive panel shifts occurred even in cold and snowy weather conditions.
- At a lateral axle load of 15 kips (and a 20-kip vertical axle load), the track panel experienced much higher cumulative deformations when the rails were in

compression (approximately +40 kips) than when they were in tension (approximately -80 kips). However, when the lateral axle load was low (5-kip lateral force, but with the same 20-kip vertical), deformation growth did not increase with rail compression.

- In-motion track panel shift tests showed concrete-tie track sustained higher (15 to 30 percent) lateral axle loads than wood-tie track.
- The critical lateral load is directly related to, and can be estimated based on, the static lateral track strength. Such static lateral strength is defined as the TLV force necessary to cause a given lateral deflection (e.g. 0.05 inch) in a stationary test, and was found to be larger than the critical lateral load as determined during repeated passes. In other words, with all conditions equal, a track panel will shift more due to a rolling TLV load than a stationary load.

PANEL SHIFT AND CRITICAL LOAD

Lateral track strength plays a major role in track buckling and in the ability of the track to retain lateral alignment under traffic. Track buckling is defined as the loss of track lateral stability resulting in significant lateral deformation due to high compressive rail load at a temperature above the rail neutral temperature. Track panel shift is the growth of track misalignment due to repeated high lateral axle loads; it normally accumulates very gradually. However, when the critical load level is exceeded, panel shift increases rapidly with the number of repeated load applications. Exhibit 1 shows the result of a rapid track panel shift when the applied lateral axle force was higher than the critical load. As shown, the controlled in-motion track panel shift was performed in the winter during snowy conditions; as such, high thermally induced rail force did not cause this shift.

The definition of the critical lateral load can be based on either accumulated or



incremental deformation after each load pass (Exhibit 2a&b). Both definitions give the same critical lateral load, but it is easier to determine the critical value given the incremental deformations. Note that with each load pass, the increment of total deformation (elastic plus residual) remains constant for a stable track. Below critical loads, this happens because the elastic deformation remains constant while the residual deformation tends to zero. However with each load pass over a segment of unstable track, the elastic deformation increment will grow — as will the residual deformation increment. At or above critical loads, this is due to an ever weakening track (less stiffness). The physical meanings of incremental and cumulative deformations are also shown in Exhibit 3.

In order to estimate the critical lateral load, as depicted in Exhibit 2a&b, repeated TLV passes were performed over any given track zone. Lateral and vertical axle loads were held constant for each test series. Between different test series, the combination of lateral and vertical axle loads was changed to determine the critical lateral load, and the effects of axle loads on panel shift growth.



Section of TTC's Balloon Loop showing a shifted panel.



Closeup view of tie end showing shift of several inches.

Exhibit 1. Examples of Rapid Panel Shift

Research by the French National Railways (SNCF) suggests that the limiting lateral axle load be defined as the following equation (Prud'homme criteria) for preventing excessive track panel shift (G. Cervi, High Speed Rail Track Structure Design and Maintenance, TRB, 1994):

$$L_c = 0.85 (2.25 + 0.33V) \quad (\text{kips})$$

where L_c =critical axle load, V =vertical axle load (kips).

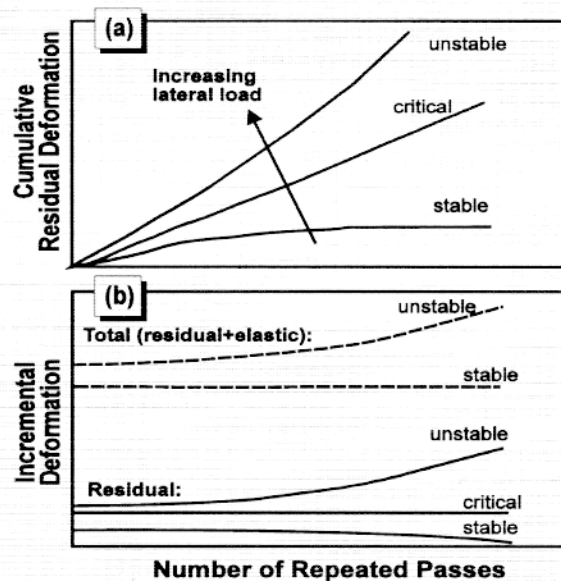


Exhibit 2a&b. Deformation Patterns Indicative of Critical Lateral Load

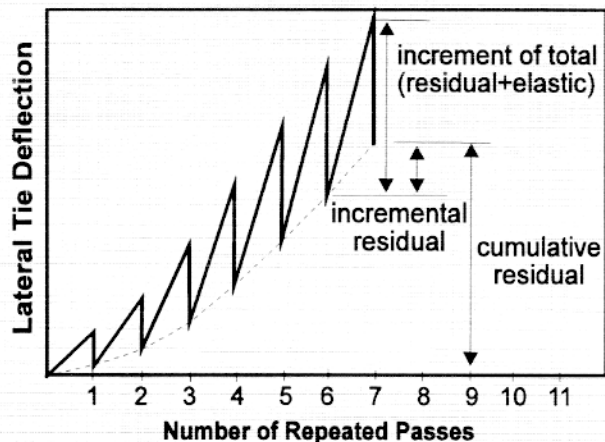


Exhibit 3. Typical In-Motion Panel Shift Behavior (unstable case)



RESULTS

Exhibit 4 shows the effect of rail longitudinal forces on residual deformation growth. Tests were conducted at two different rail temperatures (i.e., two rail longitudinal forces). At each longitudinal force, the first 16 passes were conducted with a lateral axle load of 5 kips; the subsequent 20 runs were conducted with a lateral axle load of 15 kips. Results shown in this exhibit represent the average of three wayside deflections over a distance of 10 ties.

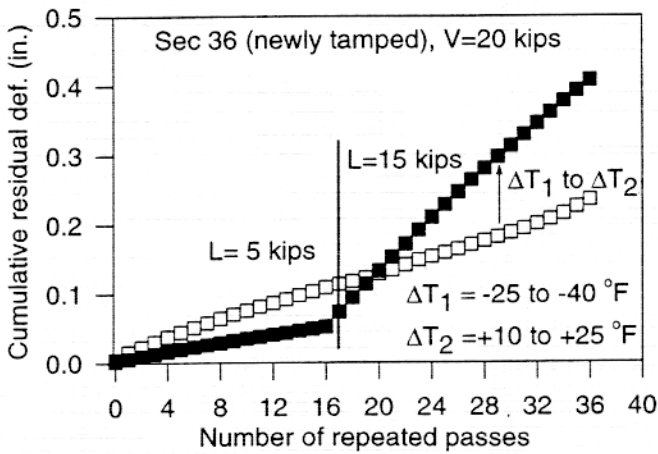


Exhibit 4. Effects of Rail Longitudinal Force

At the lower lateral load, an increase in rail longitudinal force from 80 kips tension (+/-20 kips) to 40 kips compression (+/-20 kips) did not accelerate residual deformation growth. However, after the lateral axle load was increased to 15 kips, the residual deformation growth was significantly faster at the high temperatures than at low-rail temperatures.

Exhibit 5 shows the effects of lateral axle load on incremental deformations between subsequent TLV passes. As expected, larger lateral axle loads resulted in higher incremental deformations. Given the critical load definitions (Exhibit 2b) this critical lateral load (with a vertical load of 20 kips) is estimated to be between 15 kips and 20 kips.

Exhibit 6 shows estimates of several critical lateral loads determined using various vertical axle loads. These tests were conducted

on Transportation Technology Center's Heavy Tonnage Loop over consolidated ballast. As shown, the critical lateral loads are 15 to 30 percent higher for concrete-tie track than for wood-tie track. The following equation gives an approximate relationship between the critical lateral load and vertical axle load for consolidated ballast and wood ties:

$$L_c = 6 + 0.5V \quad (\text{kips})$$

For comparison, the critical lateral loads predicted by the Prud'homme criteria are shown as a dashed line in Exhibit 6. These are approximately 50 percent of the values obtained during TLV tests (the Prud'homme criteria incorporates a safety factor of 0.85).

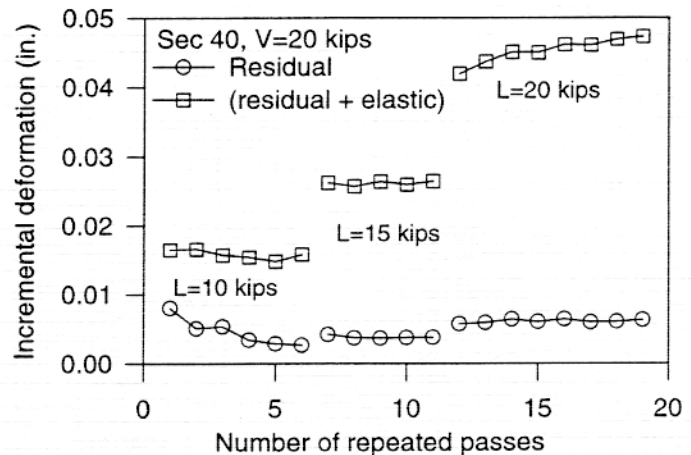


Exhibit 5. Effects of Lateral Axle Load

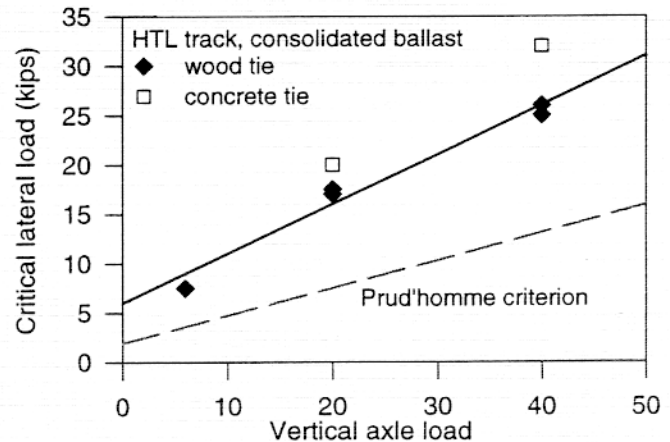


Exhibit 6. Critical Lateral Loads

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

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