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Assessing Railroad Stress State through TLV Gage Strength Testing

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Summary

Reducing the stress state of railroads is an industry initiative undertaken by North American railroads. Being able to assess the actual stress state of a railroad track will certainly help in selecting solutions to reduce the stress state. As an enhancement to the gage strength testing capability of the Track Loading Vehicle (TLV), Transportation Technology Center, Inc. (TTCI) has developed a method to assess the stress state of track structure in terms of gage strength.

In this assessment, the stress state is measured by the amount of lateral gage spreading load that exceeds the track structure gage-restraining capability. In the method developed for stress state analysis, the major step is to convert gage strength test results in terms of delta gage to a distribution of gage strengths in terms of allowable gage spreading load. Final steps in the analysis are to obtain the actual lateral load distribution exerted on the track and compare it with the gage strength distribution. If there is intersection between the two distributions, the affected portion of track is considered to be overstressed and may be prone to rapid degradation. The lateral load distribution can be determined either from a truck performance detection site or from instrumented wheelset testing.

Over the past several years, TTCI has conducted extensive gage strength testing in revenue service, using the TLV. This digest describes how the test results are used for stress state analysis and illustrates the effects of traffic and track parameters, such as tonnage, curvature, and track components, on the stress state of railroad tracks.

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INTRODUCTION

For the past decade, railroads have seen a continuous increase in axle loads and consequently higher stresses on the track structure. In order to determine the effect of these higher stresses and corresponding maintenance costs, it is important to assess the stress state of railroad tracks. The stress state of track is defined as the intersection of the track strength distribution with its corresponding load distribution. If there is a significant intersection between the two, the track is said to be overstressed and is prone to rapid degradation.

Over the past several years, TTCI's Track Loading Vehicle (TLV) has been used to collect track strength data on railroads in different parts of the United States. The data collected has enabled TTCI engineers to develop a method to assess the stress state of railroad tracks. This *Technology Digest* presents the method developed and results obtained for the revenue service tracks tested. Assessments have been done for tracks on an eastern railroad and a western railroad to show the effects of parameters, such as traffic and track condition, on the stress state of tracks.

Stress State of Track Structure

Track gage strength is measured based on gage spreading (i.e., delta gage = loaded gage – unloaded gage) under a given test load (33 kip vertical and 18 kip lateral for the TLV test). Under the given test load, higher rail deflection means lower track strength. However, for the stress state analysis, track gage strength needs to be defined in a different manner.

For stress state analysis, track gage strength needs to be defined as the amount of lateral load required to generate an allowable track gage widening (e.g., 0.75" or 1.0"). Given an allowable gage widening of 1.0 inch, the lateral load required to produce this deflection may vary from 20 kip to 40 kip. Obviously, the segments that require 40 kips to generate such a deflection would have higher gage strength than segments that only require 20 kips.

After a gage strength distribution in the terms of allowable gage spreading load is determined over a segment of track, it can be compared to a lateral load distribution for stress state analysis. There are two ways to determine actual loads that are applied on the track. The first way is to use instrumented wheelset data. This, however, is specific to the test vehicle type. The second way is to use loads recorded from truck performance detector (TPD) sites for the distributions of many vehicle types. This type of distribution, however, is specific to the TPD sites.

Determining Gage Strength Distribution

During a TLV gage strength test, constant 18-kip lateral and 33-kip vertical wheel loads are applied to each rail of the track. The collected data provides unloaded gage, loaded gage, and delta gage (DTG) information. A histogram based on test data, such as DTG, collected at the 18-kip load level, can be produced for a given segment of track.. Figure 1 shows an example of gage strength distribution in the terms of DTG.

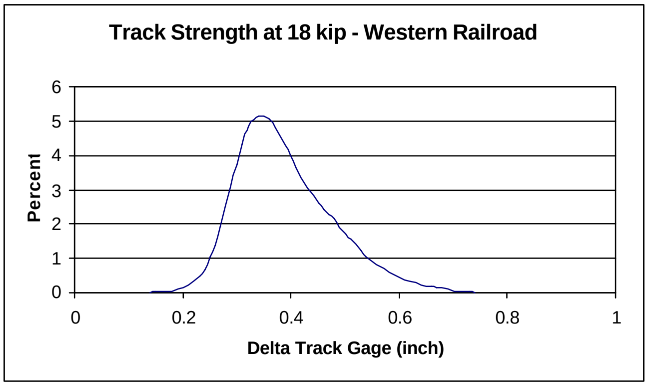

Figure 1. Track Strength at 18 kip TLV Lateral Load

However, since tracks are exposed to a wide variety of lateral loads, not just 18 kips, it is necessary to translate the gage restraining strength at 18 kips to a wider range of lateral loads. The approximate conversion is done through the following equation (assuming 33 kip vertical wheel load). This equation was derived based on the research results obtained by Volpe National Transportation Systems Center:[1]

$$DTG\ (@LL_{new}) = DTG\ (@LL_{18}) * \{(0.0918 * LL_{new}) - 0.652\}$$

Where

$DTG\ (LL_{new})$ = Delta gage at the desired lateral load

$DTG\ (LL_{18})$ = Delta gage at 18 kip lateral load (TLV test load)

LL_{new} = Desired lateral load

The above equation is intended to estimate gage spreading (DTG) over a range of lateral loads based on the TLV test results. In this study, gage spreading was estimated for lateral loads ranging from 8 kip to 50 kip (again, the TLV test load is 18 kips). From this procedure, gage strength distributions (in the format for stress state analysis) were then determined for various tracks with various conditions. Figure 2 shows an example of a gage strength distribution determined from this procedure for a portion of track on a western railroad. Notice the distribution is now in terms of allowable lateral load.

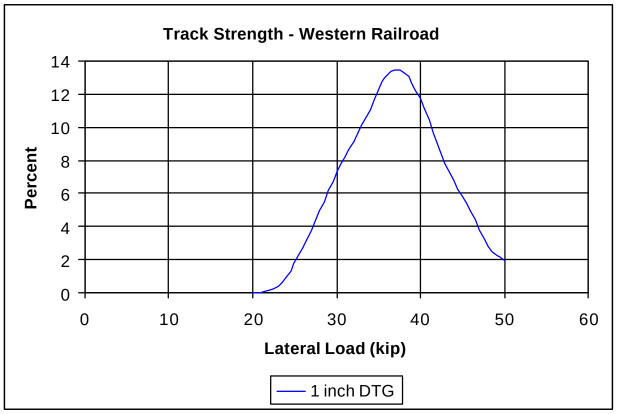

Figure 2. Example of Gage Strength Distribution for Stress State Analysis

A gage strength distribution generated from this procedure depends on the allowable DTG (e.g., 0.75" or 1"). Determining the level of allowable DTG on a track is left up to the railroad. However, there is a close correlation between track class and allowable DTG, with higher track classes allowing lower levels of DTG. Choosing a lower value of allowable DTG (e.g., 0.75") will result in a gage strength distribution shown in Figure 2, shifted to the left, meaning that this track may allow lower magnitudes of actual lateral loads.

A statistical approach was employed to deal with the massive amounts of gage strength data collected in revenue service. To do so, a track is divided into consecutive segments (e.g., 0.1 mile in length), and statistical values such as maximum, minimum, average, and 95th percentile were obtained from gage strength test results. The conversion procedure is then used to produce gage strength distributions from the statistical values. For example, a gage strength distribution derived based on average DTG results would represent average track strengths, a gage strength distribution based on maximum DTG results would represent the lowest track strengths, and a gage strength distribution based on the minimum DTG results would represent the highest track strengths.

Obtaining Load Distribution

The TLV has repeatedly tested three primary routes in the east, west and mid-west over the past few years. In an attempt to determine the general level of lateral loads experienced by these routes, data from TPD sites near these locations were analyzed.

Figure 3 shows the track strength of the weakest portions of track on a western railroad along with the loads experienced by the track as determined by a nearby TPD. The intersection of the TPD histogram with the track strength histograms represent overstressed track. With a 1.0-inch allowable DTG, the amount of overstressed track is minimal. Notice, however, that the lateral load data collected from a TPD site does not include those higher loads at places where track conditions are poor due to rough track geometry and sharp curves.

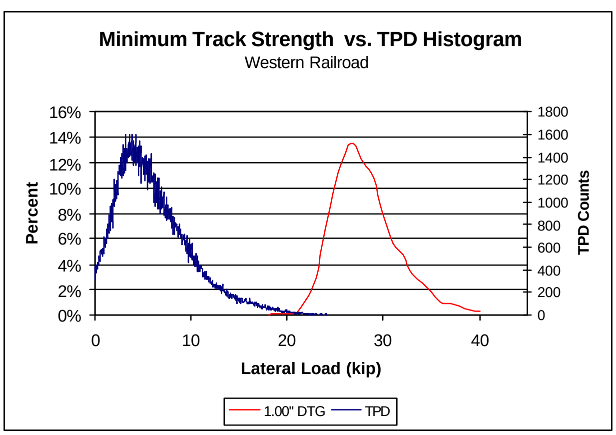

Figure 3. Using TPD Load Data for Analysis

Effects of Parameters on Track Strength

Track strength distribution in any given area is dependent on many factors. The following examples show the effect of gage strength degradation due to traffic (MGT), curvature, and tie type. Obviously, these factors would affect the outcome of the stress state analysis.

Figure 4 shows how track strength was degraded by traffic for a western route. The accumulated tonnage (MGT) shifted the track strength distribution to the left, indicating reduced capability of track to resist gage spreading.

Figure 5 shows the effect of curvature on the gage strength distribution for an eastern railroad track (primarily wood ties). As expected, curvature had a significant effect on the strength of the track tested. In other words, track segments in sharp curves are subjected to higher lateral loads; therefore, track segments in sharp curves are subjected to a higher stress state.

Figure 6 shows the comparison of gage strength distributions between concrete tie and wood tie tracks for a western railroad. As expected, concrete tie track is stronger than wood tie track.

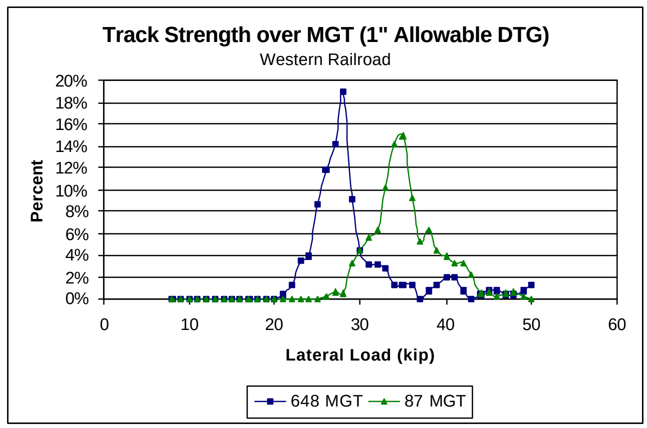

Figure 4. Example of Effect of Traffic on Gage Strength Degradation

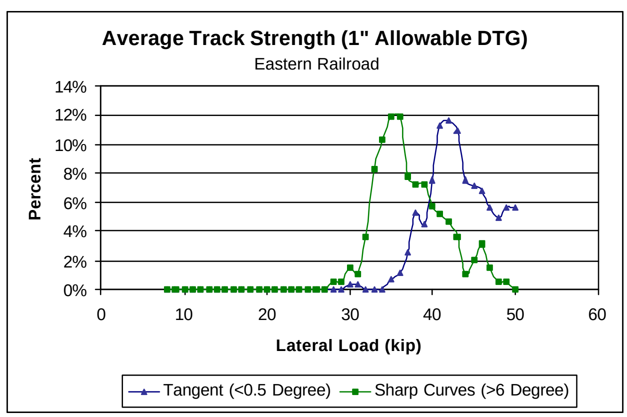

Figure 5. Effect of Curvature on Gage Strength

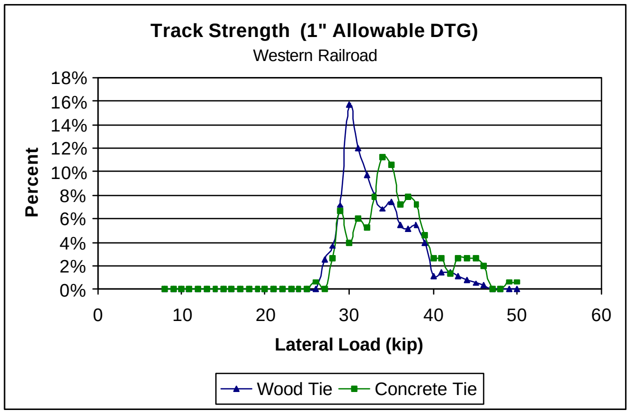

Figure 6. Effect of Tie Type on Gage Strength

Summary

TTCI has developed a method of assessing the stress state of track based on the analysis of gage strength measurements following these steps:

1. Define an acceptable level of allowable DTG.
2. Generate track strength distributions based upon gage-strength test results using TLV data.
3. Obtain actual loads exerted on the track.
4. Compare the load distribution with track strength distribution to determine how much of the track is overstressed.

Acknowledgements

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Reference

1. Coltman, M., Dorer, R. and Boyd P. "The Development of Automated Survey Techniques for Evaluating Tie and Rail Fastener Performance." Applied Mechanics Rail Transportation Symposium, ASME, 1988, AMD-Vol. 96, RTD-Vol.2.

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