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## Rail Car Lateral Forces for Bridge Design and Rating

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### Summary

Through the Association of American Railroads' (AAR) Strategic Research Initiative Program, Transportation Technology Center, Inc. (TTCI) is developing guidelines for assessing and extending the life of steel railroad bridges. As a part of the process, TTCI quantified the current lateral force environment using over-the-road data from load-measuring wheelsets and wayside measurements from truck performance detectors (TPD) and wheel impact load detectors (WILD).

Results from these tests are being used to review the lateral force guidelines used by AREMA for design and rating of steel bridges. Maintenance of lateral bracing members is typically a major portion of a railroad's steel bridge maintenance budget. The data from this research should promote better design and rating of these members. Better ratings allow for better prioritization of limited maintenance funds.

The following results were obtained from this study:

- Current AREMA design guidelines for lateral forces from equipment appear to be adequate.
- Dynamic measurements of net truck lateral forces from over-the-road and wayside data show that 99.95 percent of the forces are less than about 15 kips at most locations.
- Higher total lateral forces on bridges might result from adjacent trucks of coupled cars.
- Ratio of the highest measured net truck lateral force to nominal vertical axle load is about 20 to 25 percent, in agreement with the current AREMA recommendation for steel bridge design.
- Net truck lateral forces show a moderate increase with an increase in train speed. The highest forces were recorded for 70 mph traffic.
- Net truck lateral forces measured over bridges are not significantly different from those forces measured on open track.

Other lateral forces acting on bridges include wind and seismic forces. Other forces acting on lateral bracing members may include out-of-plane bending of girders, non-uniform deflection of girders, displacement-induced bending of braces, vibrations due to dynamic loading, impact, and longitudinal forces. These forces are the subject of other studies or future research.

The TPD and WILD data used in this study includes traffic from intermodal, mixed freight, passenger, and unit trains. The over-the-road data includes a coal gondola, a covered hopper, and a tank car, both loaded and empty.



**INTRODUCTION**

TTCI measured dynamic net truck lateral forces using over-the-road (OTR) data and wayside data. The purpose of the measurements was to determine the lateral forces that are imparted to steel railroad bridges. Repair of lateral bracing members is one of the biggest expense items in the maintenance of steel railroad bridges. Lateral bracing members are designed to resist lateral forces from equipment, thermal forces, and longitudinal forces.

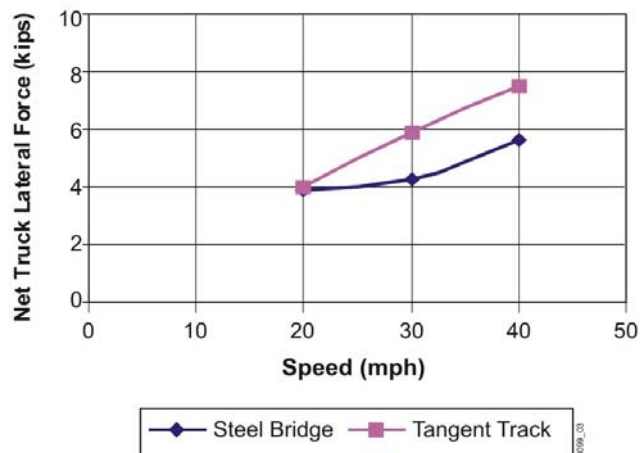
The highest observed forces are near the lateral force level currently recommended for design of steel bridges. The ratio of the highest measured net truck lateral forces to vertical axle loads is about 20 to 25 percent, in agreement with the current AREMA guidelines. The OTR data provides forces experienced by single railcars operated over hundreds of miles of track. The wayside data provides forces experienced at specific track locations by the passing of millions of railcars.

In 1936, the AREA design lateral force for steel bridges was a single moving lateral force of 20 kips. Current AREMA guidelines for steel bridges recommend designing for “a single moving concentrated lateral force equal to one-quarter of the weight of the heaviest axle of the specified live load.” For the current E-80 design, the lateral force is still 20 kips. For shorter spans governed by the alternate live load, the design lateral force is 25 kips. While there have been increases in the vertical design load over the years, the lateral force from moving equipment has remained at 20 kips for many spans. For the previous E-72 design, the 20 kips lateral force for design was about 28 percent of the heaviest axle load. The European experience suggests a similar ratio.<sup>1-7</sup>

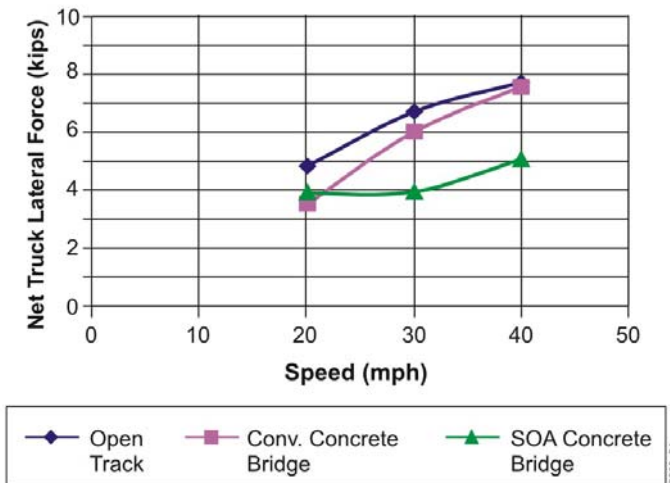
This research did not attempt to study lateral forces due to wind, seismic activity, or centrifugal forces. These forces are not subject to significant change with the introduction of new equipment and vehicle designs. Furthermore, the design criteria for wind and centrifugal forces are generally well established.

**TEST MEASUREMENTS**

Initial test measurements were performed at the Facility for Accelerated Service Testing. Lateral forces from instrumented wheelsets (IWS) in a 315,000-pound coal gondola were recorded on the steel and concrete bridges and compared to those in open track. No statistically significant differences were noted. Figures 1 and 2 summarize the 95<sup>th</sup> percentile data for the open-deck steel bridge and the ballast-deck concrete bridges respectively. This conclusion allowed the use of a significant amount of wayside and OTR test data to be used for the bridge study. This conclusion is not surprising, as there is no compelling reason to expect different net truck lateral forces on a bridge as compared to open track. The European experience is similar.<sup>6</sup>



**Figure 1. Comparison of 95<sup>th</sup> Percentile Net Truck Lateral Forces on Open Track and Open-Deck Steel Bridge at FAST**



**Figure 2. Comparison of 95<sup>th</sup> Percentile Net Truck Lateral Forces on Open Track and Ballast-Deck Concrete Bridges at FAST**

Instrumented wheelsets measuring the wheel/rail interaction forces were also used to gather data on about 1500 miles of track and on three railroads. The onboard IWS system is capable of capturing the variation in loads on a single car due to vehicle dynamics in response to track geometry and train handling. The following load environments were obtained from recent tests as part of other AAR research programs.<sup>8</sup>

- 263-kip Covered Hopper - Loaded
- 263-kip Tank Car - Loaded & Empty
- 263-kip Coal Gondola - Loaded

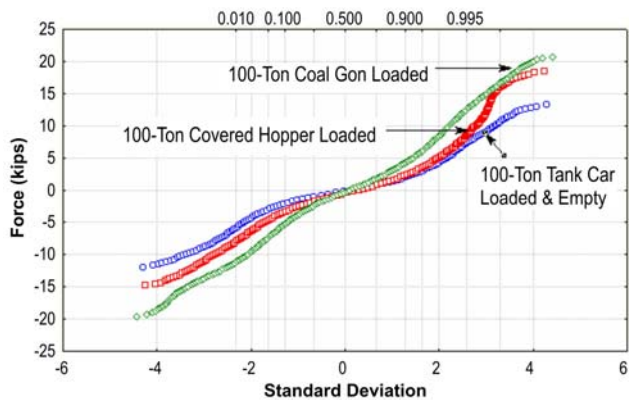
IWS data from these tests was taken in conjunction with train speed and track geometry data, so it was possible to separate out the centrifugal forces due to track curvature.

Table 1 shows the 95, 99.5, and 99.95 percentile values of net truck lateral force (NTL) for each vehicle type used in this study. Note that while these forces are for 263-kip cars with 66-kip vertical axle loads, it is important to consider the ratio of lateral force to vertical axle load. The ratios of the 99.95 percentile values for the covered hopped and the coal gondola to the 66-kip vertical axle load are just under 25 percent, which is the ratio currently recommended for design. Approximately 400 to 500 miles of data were obtained for each vehicle type.

Figure 3 shows the cumulative distribution plot of net truck lateral forces for each of the three vehicles tested.

**Table 1. Net Truck Lateral Forces for Three Vehicles in Revenue Service**

Vehicle	95.0% Net Truck Lateral Force (kips)	99.5% Net Truck Lateral Force (kips)	99.95% Net Truck Lateral Force (kips)	Miles
263-kip Covered Hopper	3.0	8.0	16.0	400 to 500
263-kip Tank Car Loaded & Empty	3.0	7.2	10.6	400 to 500 ½ Loaded & ½ Empty
263-kip Coal Gondola Loaded	6.0	12.4	16.4	400 to 500



**Figure 3. Net Truck Lateral Forces from OTR Measurements**

Wayside measurements are capable of gathering data from a large number of passing trains including different types of equipment. Wayside detectors are currently in use at locations on several railroads throughout North America. Data measuring net truck lateral force on tangent track were obtained from 11 different wayside sites (Table 2).

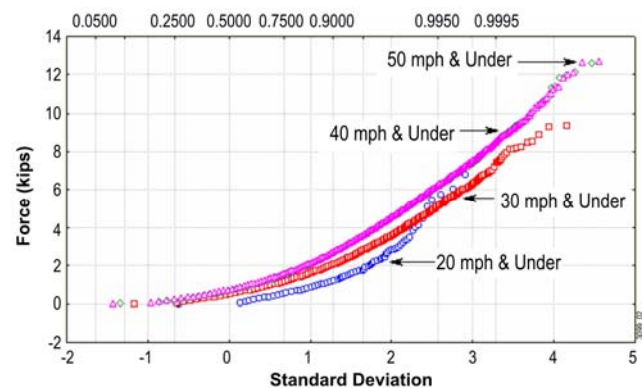
The values shown in Table 2 and Figure 4 are for locations where the axle loads can be as high as 79 kips for 315-kip equipment. Since the maximum axle loads are so close to the E-80 design axle load, the force values can be compared directly to the 20-kip or 25-kip design lateral forces.

The traffic included in the wayside data consisted of unit trains, intermodal, mixed freight, and passenger trains. Nearly 10 million trucks passing wayside sites were analyzed. Wayside data was sorted by 10 mph speed increments up to the maximum recorded speed. The maximum allowable speed was governed by the railroad timetable for each location.

Figure 4 shows the cumulative distribution plot of net truck lateral forces for each speed range for a typical wayside site.

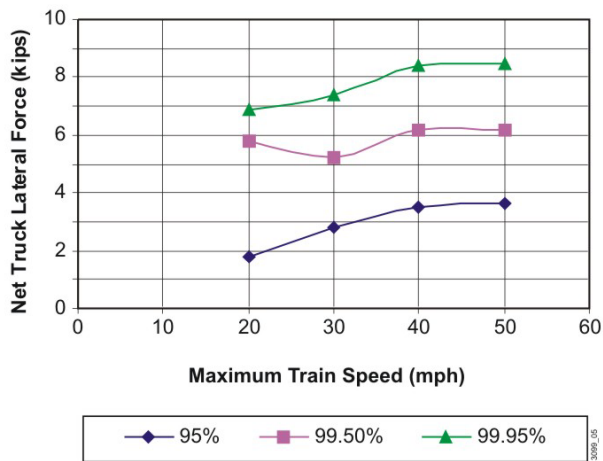
**Table 2. Net Truck Lateral Forces from Wayside Detectors**

Wayside Sites	95.0% NTL	99.5% NTL	99.95% NTL	Number of Trucks
IA	6.4	10.1	13.6	614,214
ID	3.3	6.9	10.2	991,564
CA 1	4.3	7.1	9.8	1,179,110
CA 2	5.9	9.3	11.6	875,740
NE 3	4.6	7.6	10.5	851,376
MO	6.0	10.5	13.2	696,016
OR	7.7	11.9	15.4	154,598
MN	4.2	6.9	9.2	665,152
AZ	4.6	8.5	12.5	2,012,950
NE 1	2.6	5.4	9.8	1,536,973
NE 2	6.7	12.4	21.8	199,174
Total				9,776,867



**Figure 4. Net Truck Lateral Forces from a Typical Wayside Detector Site**

Figure 5 shows the effect of train speed on net truck lateral forces from the same typical wayside site. Note the moderate increase with increasing train speed, as might be expected.



**Figure 5. Effect of Train Speed on Net Truck Lateral Forces from a Typical Wayside Detector**

## Implementation

TTCI engineers are working with AREMA Committee 15 to evaluate and update the lateral force guidelines for steel bridges. The data suggest that the current design lateral force equal to 25 percent or 1/4 of the nominal vertical axle load is appropriate, corresponding to the highest forces measured at the 99.95 percent level.

For rating purposes, the 95 or 99.5 percent levels are more appropriate. A further reduction for reduced speed does not seem to offer much additional benefit, once again similar to the European experience.<sup>1-7</sup>

## FUTURE RESEARCH

Future research plans include measurement of strains in various bracing members of the steel bridge at the Facility for Accelerated Service Testing. Measurements will include axial strains, as well as strains in several bending modes. These tests will help quantify the actual axial and bending forces in bracing members. Typically such members are only designed for axial force. But experience suggests that bending stresses in bracing members might be significant.

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