

### DISTRIBUTION OF VERTICAL LOADS IN THE TRACK STRUCTURE

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#### Summary

Recent test results indicate the use of improved-design trucks under 39-ton axle load traffic may make little difference in the distribution of the vertical load paths from the rail to the subgrade. The primary goal of the Heavy Axle Load (HAL) Load Path Evaluations is to measure the vertical load distribution generated by 33- and 39-ton axle load traffic in a controlled setting at the Federal Railroad Administration's (FRA) Transportation Technology Center near Pueblo, Colorado. Data collected will be used to evaluate the vertical-load imprint on the track structure induced by different car and truck designs.

The differences in measured rail-seat loads and subgrade pressures between the 33- and 39-ton axle load traffic are noticeable, particularly in the control zone with the stiffer subgrade. The differences between the conventional and improved-suspension trucks are less evident. The differences due to the increase in axle load and the difference in the two truck designs is less evident in the low-modulus test zone. The noticeable differences in the control zone may be attributed to fewer ties sharing the vertical loads in the stiffer subgrade, resulting in higher load concentration per tie.

Fifty percent or more of the subgrade pressures measured in the low-modulus test zone under HAL traffic exceeded the calculated subgrade strength, resulting in the over-stressing of the subgrade. The low-modulus zone has a calculated strength level of about 12 psi, while the calculated subgrade strength in the control zone is at least twice that of the low modulus. Less than 0.5 percent, if any, of the measured subgrade pressures in the control zone exceeded their calculated strength.

The experiment was jointly sponsored by the FRA and the Association of American Railroads.



#### Suggested Distribution:

- Bridges and Roadway
- Maintenance of Way
- Maintenance Planning
- Track Maintenance

Association of American Railroads  
Railway Technology Department

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## INTRODUCTION AND CONCLUSIONS

Improved-suspension trucks have been shown to make little difference in the vertical load-path distribution under 39-ton axle load traffic in the Heavy Axle Load (HAL) Load Path Evaluations jointly sponsored by the Federal Railroad Administration (FRA) and the Association of American Railroads (AAR). The current goal of the experiment is to measure the loads generated by 39-ton axle load improved-suspension traffic from the rail through the subgrade.

Vertical load path measurements were taken during three different measurement cycles with conventional three-piece trucks during the second phase of the HAL program at the FRA's Transportation Technology Center (TTC) near Pueblo, Colorado. At the conclusion of the second phase of the HAL program, the train was fitted with improved-suspension trucks, which are designed to reduce the dynamic forces transmitted to the track structure. Load path measurements were then taken during two separate measurement cycles under the improved trucks.

## TRACK STRUCTURE

The two test zones, located on tangent track of the High Tonnage Loop (HTL), at the Facility for Accelerated Service Testing (FAST) are shown in Exhibit 1. With the exception of one variable, construction of the track structure is similar in

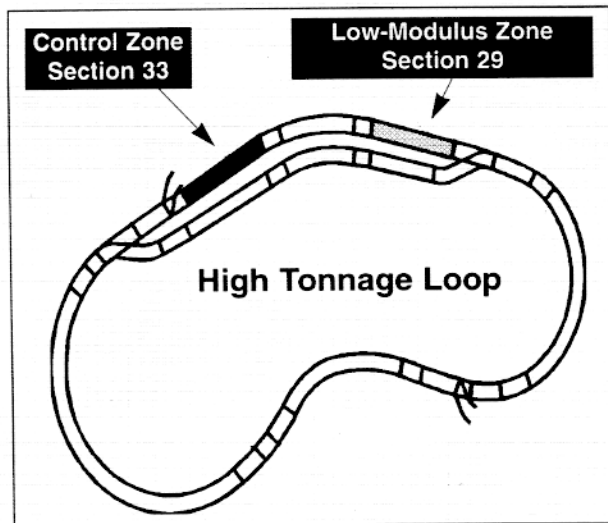


Exhibit 1. Test Zone Locations

both test zones. Each test zone consists of 136-pound continuous welded rail, 7" x 9" x 8'6" hardwood cross ties, a 12-inch layer of AREA 4 gradation granite Gneiss ballast, and 6 inches of compacted sub-base material. The difference is in the subgrade support conditions. The control zone in Section 33 has typical FAST subgrade support conditions (track modulus of around 4,500 lbs/in/in), and Section 29 has a low modulus subgrade (track modulus of approximately 2,000 lbs/in/in).

## DATA COLLECTION

Dynamic and static measurements were taken in both test locations under the HAL train. Baseline data was initially collected under the HAL train equipped with standard trucks, and later with the HAL train equipped with the improved-suspension trucks. Dynamic data consisted of rail loads collected using strain gage circuits, rail-seat loads collected using instrumented tie plates, and stresses at the sub-ballast/subgrade interfaces measured using pressure cells. Exhibit 2 illustrates a cross section of a typical instrumentation setup.

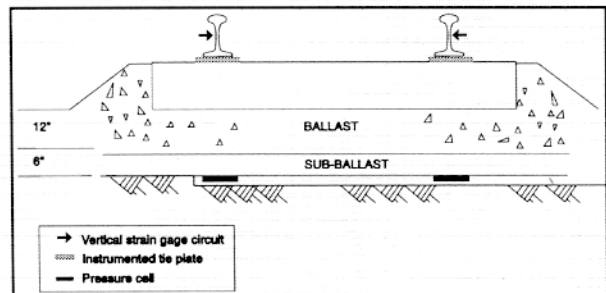


Exhibit 2. Instrumentation Setup

## RESULTS

Wheel/rail loads were measured at the rail in both test zones under 33- and 39-ton axle load cars equipped with conventional trucks. Loads were also measured under the 39-ton axle load cars with improved-suspension trucks. The histogram of vertical wheel loads shown in Exhibit 3 includes data from both the control and low-modulus test zones. There was very little difference in the measured wheel loads over both the control and low-modulus test zones. However,



the increase in axle load from 33 to 39 tons is distinct in both zones, as shown in Exhibit 4.

Exhibit 3 also shows that there are minimal differences in the vertical wheel loads measured under the 39-ton axle load cars under both conventional and improved-suspension truck designs.

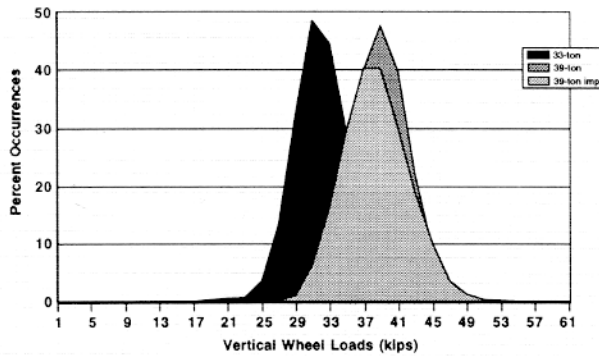


Exhibit 3. Histogram of Vertical Wheel Loads Measured at the Rail

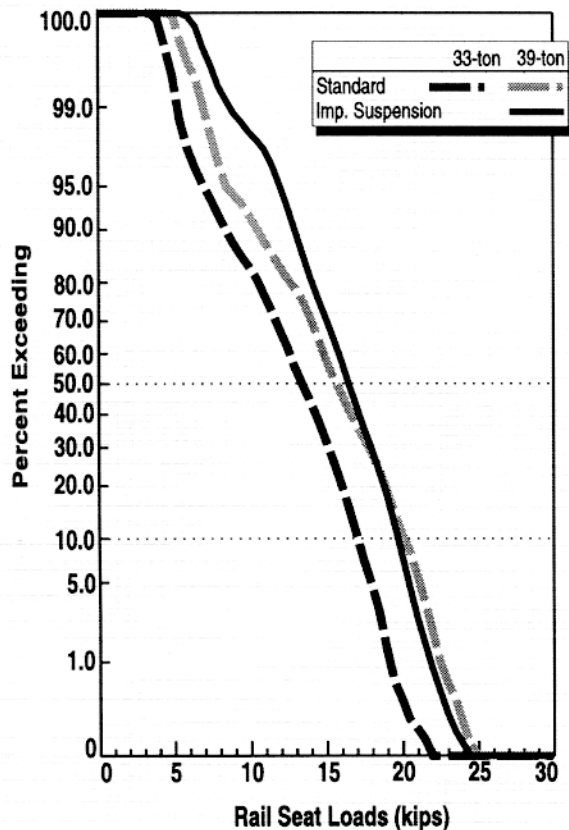


Exhibit 4. Cumulative Distribution of Rail-Seat Loads in the Control Zone

Tie plates instrumented with strain gages were used to measure the loads on the rail-seat area of the tie. As with the vertical wheel loads measured at the rail, there was very little difference in measured rail-seat loads under both truck designs. The increase in axle load from 33 to 39 tons is also evident at the rail-seat load area. Exhibit 4 shows the cumulative distribution of the rail-seat loads measured in the control zone.

The measured rail-seat loads in the low-modulus test zone also show little difference between the two truck designs, as shown in Exhibit 5. The increase in axle load from 33 to 39 tons is less apparent in this zone. This small difference in measured loads may be attributed to more ties sharing the vertical loads in a lower modulus subgrade, resulting in the loads being distributed over a longer influence zone.

The magnitude in axle-load-induced stresses measured at the subballast/subgrade interface is also evident at this level. In the past, the assumption was made that wheel loads dampened out by the time they reach the subgrade, thus an increase in axle load from 33 to 39 tons would not be as evident at this level. However, the subgrade is just as sensitive to the increase in axle loads as the track structure and its components.

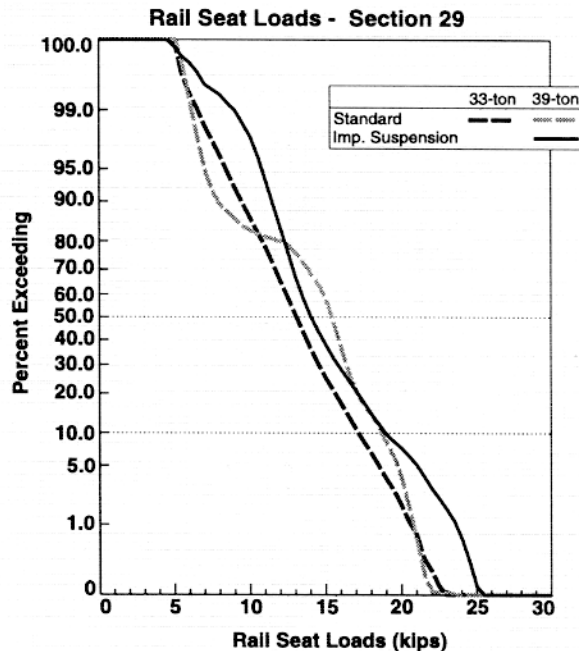


Exhibit 5. Rail-Seat Loads in Low-Modulus Zone



The histogram in Exhibit 6 shows the median pressures measured in the control low-modulus zone under 33- and 39-ton axle load cars equipped with conventional trucks, and 39-ton axle load cars equipped with improved trucks. As expected, an increase in subgrade pressures due to the increase in axle load is evident. However, the difference between the two truck designs under 39-ton axle load traffic is less significant. Fifty percent or more of the subgrade pressures measured in the low-modulus test zone under HAL traffic exceeded the calculated subgrade strength, resulting in the over-stressing of the subgrade. The low-modulus zone has a calculated strength level of about 12 psi, while the calculated subgrade strength in the control zone is at least twice that of the low-modulus zone.

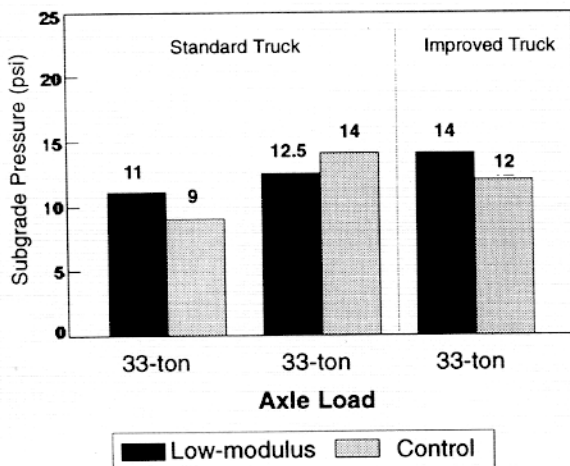
Exhibit 7 shows a histogram of the 90th percentile pressures measured in both zones. There is very little difference in the magnitude of subgrade pressures measured in the two zones. However, there is more variation in the subgrade pressures measured in the control zone. The differences due to the increase in axle load, and the

differences between the two truck designs, are more evident in the control zone which has the stiffer subgrade. As mentioned earlier, these noticeable differences in subgrade pressures in the control zone may be attributed to less ties sharing the vertical loads in the stiffer subgrade. This could result in higher load concentration per tie.

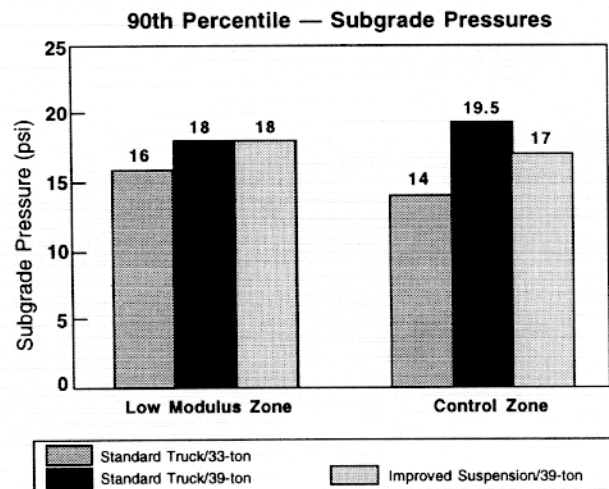
Since there was no significant difference between the wheel forces measured at the rail, the small difference in subgrade pressures between the two different truck designs is possibly due to a combination of the difference in track geometry at time of measurement and the measurement error. Subgrade pressure measurements under the improved-suspension trucks continue in order to monitor reductions in subgrade stress, as well as improvements in track-geometry retention.

1. Read, David M. and Li, Dingqing, "Subballast Considerations for Heavy Axle Load Trackage," Technology Digest (HAL) September 1995, Pueblo, Colorado.

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**Exhibit 6. Cumulative Distribution of Subgrade Pressures in the Control Test Zone**



**Exhibit 7. Cumulative Distribution of Subgrade Pressures in the Low-Modulus Test Zone**

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