TECHNOLOGY DIGEST
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PRELIMINARY RESULTS OF CONCRETE TIE STRAIN MEASUREMENTS AT FAST

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Summary

The Concrete Tie experiment is evaluating the effects of Heavy Axle Load (HAL) traffic on concrete tie performance. The test has been in place at the Facility for Accelerated Service Testing (FAST) in Section 03, a 5-degree curve, on the High Tonnage Loop (HTL) since the beginning of the HAL program. The test is being conducted at the Transportation Technology Center (TTC), Pueblo, Colorado as part of a joint effort by the Association of American Railroads (AAR) and the Federal Railroad Administration (FRA).

Tie strains were measured at the tie center and near the rail seats under a train of twelve 33- and fourteen 39-ton axle load cars. The ties were on granite ballast where no maintenance had been performed in over 75 million gross tons (MGT). The data showed the following:

- 39-ton axle load cars produced tie center strains 15 to 35 percent higher than 33-ton axle load cars.
- Tie center strains measured under the lead axles of both 33- and 39-ton axle load cars were higher than strains measured under trailing axles.
- As much as 15 percent of the tie center strain measured could be attributed to gage spreading lateral forces.
- Because strains near the rail seats were much lower than those at the tie center, no significant differences in strain were noticed between 33- and 39-ton axle load cars near the rail seats.

Based on these results, the following needs arise for further research and testing:

- Higher tie center strains from 39-ton axle load cars could lead to reduced tie life, but this has not yet been verified.
- The use of better steering trucks with reduced gage spreading lateral forces should lead to a reduction in tie center strain.

Suggested Distribution:
☐ Operating Department
  Train Handling
☐ Operating/Engineering Department
  Bridges and Roadway
  Maintenance of Way
  Track Maintenance

Association of American Railroads
Research and Test Department

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INTRODUCTION AND CONCLUSIONS

Concrete tie strain measurements were taken at the Facility for Accelerated Service Testing (FAST) on the High Tonnage Loop (HTL) during the completion of Heavy Axle Load (HAL) Phase II operations.

Baseline strain measurements under conventional 33- and 39-ton axle load vehicles with standard 3 piece trucks, were taken in Section 03, a 5-degree curve, on the FAST/HTL. These measurements will be compared to strain measurements taken during FAST/HAL Phase III operations when the train will be equipped with advanced design trucks.

Strain gages were applied to three consecutive BN100 concrete ties equipped with McKay fasteners and 8 mm polyurethane tie pads. Tie weight of the BN100 is approximately 630 pounds. Strains were measured under the rail seat area, one inch below the chamfer at the high and low rail seats and at the top of the tie center. The ties were on granite ballast and no ballast maintenance had been performed on or near the ties for over 75 MGT. Rail force circuits were also used to measure vertical and lateral wheel forces at the same location. The data was collected under a special train, which included twelve 33-ton axle load cars and fourteen 39-ton axle load cars.

Strains measured at the tie center were significantly higher for the 39-ton axle load cars. These higher strains are not only due to the increased vertical load, but also the higher lateral gage spreading forces seen with the heavier cars. The average peak strain measured at the tie center was 110 microstrain for 33-ton axle loads and 150 microstrain for 39-ton axle loads.

As much as 10 to 15 percent of the tie center strain measured under the lead axle can be attributed to lateral gage spreading forces that result from truck steering.

The average peak strain measured under the rail seats was only 65 microstrain, much less than the tie center strains. Because of this, it was hard to notice any significant differences between 33- and 39-ton axle load cars in the strains measured at the rail seats.

TYPICAL STRAIN RESPONSE

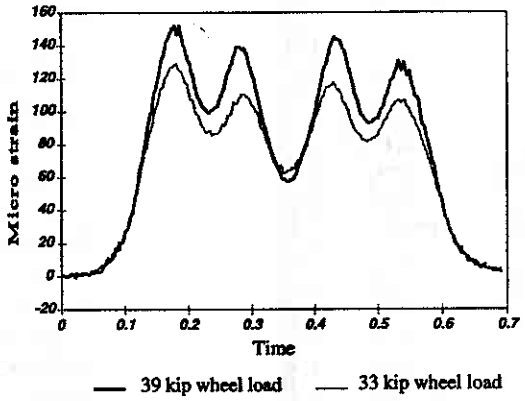

Exhibit 1. Typical Strain Response of 33- and 39-Ton Axle Load Cars

Exhibit 1 shows the typical tie center strain response to two adjacent trucks of coupled cars for both 39- and 33-ton axle load cars. The strain response of the 39-ton axle load is greater in both peak strains and the magnitude from peak to valley of each passing wheel. All tie center strains indicate tension in the top of the tie.

VERTICAL AND LATERAL FORCES

Exhibit 2 shows the vertical and lateral forces from a pair of 39-ton axle load trucks along with the associated strain at the tie center. The peaks of the lateral forces are generated by the leading axles of each truck, with the trailing truck laterals being slightly negative (sign convention is for positive lateral forces to cause gage spreading). Notice that the strain at the tie center developed by the leading axle of each truck is higher than that of the trailing axles even though there is no significant difference in the vertical loads. The higher strain is a result of the higher lateral forces generated by the leading axles.

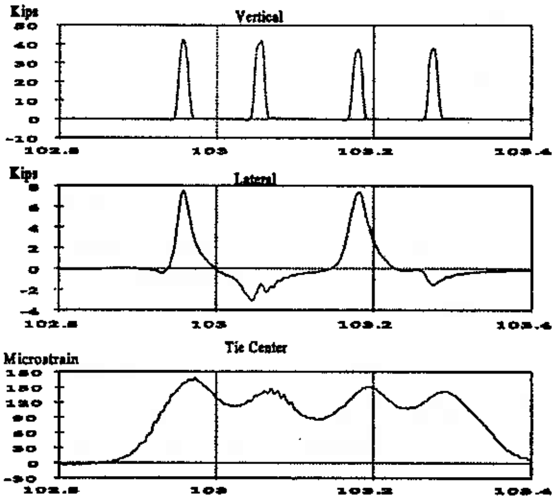

Exhibit 2. Vertical and Lateral Forces and Associated Strains - 39-Ton Axle Load Car

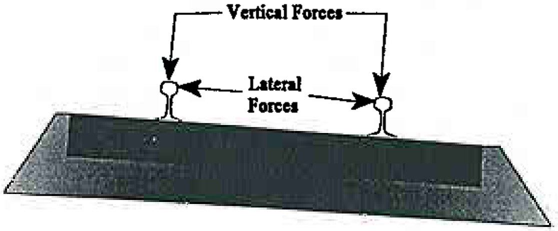

Exhibit 3. Vertical and Lateral Forces

Exhibit 3 shows how forces are input from the wheels to the rails on a curve. There is little that can be done to reduce average vertical forces since these forces are dependent on axle loads. However, a reduction of gage spreading lateral forces could lead to a reduction of tie center strain under the lead axles to a level closer to that of the trailing axles (refer to Exhibit 2), approximately 10 to 15 percent for a given axle load.

STRAIN DISTRIBUTION

Strain cycles were counted using the rainflow technique, which is commonly used in fatigue studies. For a typical passing of two adjacent trucks of coupled cars (Exhibit 1) there are a total of four cycles. For the 39-ton axle load car there is one large cycle of about 150 microstrain and three smaller cycles of about 40 to 80 microstrain. The high magnitude strain counts reflect the peak strain due to a pair of coupled trucks, while the low magnitude strain counts reflect the strain of the four individual axles. Therefore, the data show large clusters of strain cycles around 50 and 140 microstrain resulting in the bimodal distributions in Exhibits 4 and 5. The difference in magnitudes between the 33- and 39-ton axle load cars could potentially lead to reduced tie life. For different tie, axle, and truck spacings, the strain pattern and resulting cycle counts will be different.

Exhibits 4 and 5 show the strain distributions of three consecutive ties for a single train pass. These distributions were compiled using the results of a rainflow analysis. For reference, failure strain of concrete in compression is usually taken as 3000 microstrain.

The strain distribution for the 39-ton axle load cars shows average peak strains of 142 microstrain. The strains from the 39-ton axle load cars have a greater variation, particularly at the higher strains compared to the 33-ton axle load cars. The strain distribution for the 33-ton axle load cars shows average peak strains of 122 microstrain.

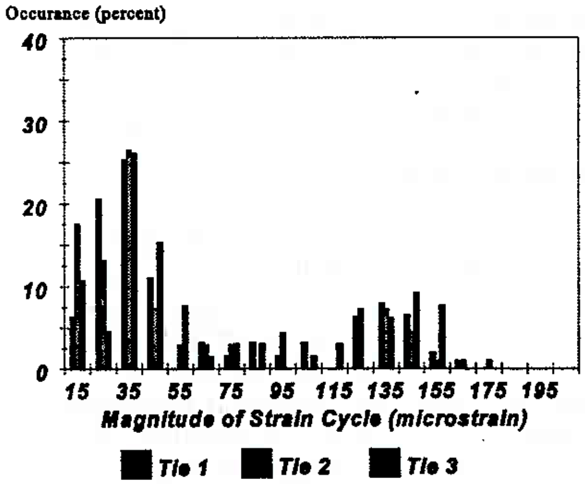

Exhibit 4. 39-Ton Axle Load-Distribution of Strain Cycles

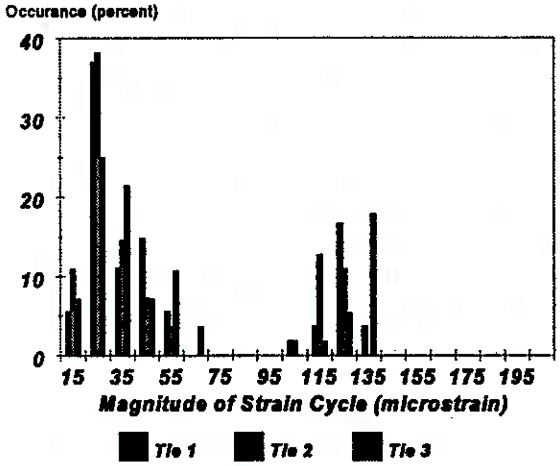

Exhibit 5. 33-Ton Axle Load-Distribution of Strain Cycles

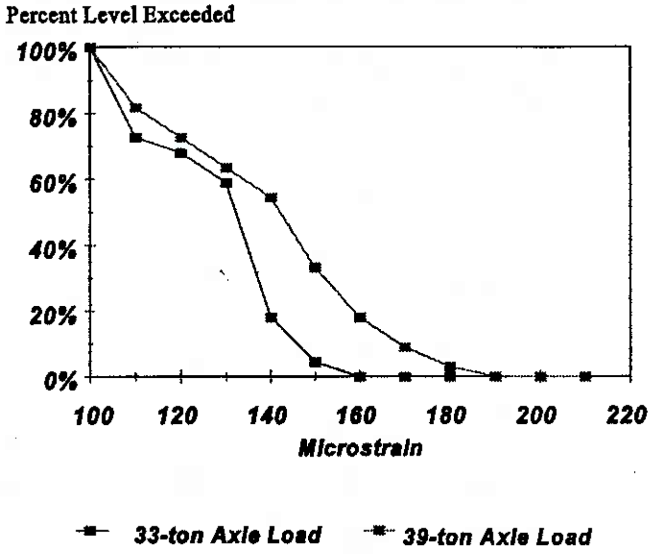

Exhibit 6. Percent Exceeded for Strains Greater than 95 Microstrain

PERCENT EXCEEDANCE

Exhibit 6 shows the exceedence plot for the measured tie center bending strains above 100 microstrain for 33- and 39-ton axle loads. The 39-ton axle load cars range from 5 to 35 percent higher than those of the 33-ton axle load cars. For example, over 30 percent of the strains measured for the 39-ton axle load cars were above 150 microstrain, compared to about 5 percent for the 33-ton axle load cars.

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