TECHNOLOGY DIGEST
Timely Technology Transfer

PRELIMINARY ANALYSIS OF HAL (286-KIP) TRAFFIC INTRODUCTION ON CONCRETE TIE CENTER BENDING STRAINS

by M. Carmen Trevizo and Rafael Jimenez

TD 97-035

Summary

Revenue service tests indicate that maximum concrete tie center bending strains measured on three concrete tie designs show an increase of 15 to 25 percent due to an increase in heavy axle load (HAL) traffic (286-kip gross rail weight cars). However, the results to date on the three designs in test—Burlington Northern (BN100), KSA, and CXT — also show that the effects of HAL may be greatly influenced by the concrete tie design stresses. These and other effects of HAL gross rail load (GRL) vehicle traffic on revenue service lines are being evaluated through the HAL Revenue Service Monitoring program sponsored by the Association of American Railroads (AAR).

The measured tie center bending strains for the CXT and KSA ties were well below the calculated design strain. Center bending strains measured on the BN100 were close to the calculated design cracking strain.

Tie center bending strains sampled under a 286-kip GRL train for the BN100 tie measured up to 83 percent of the calculated cracking strain of the tie design. At the Transportation Technology Center's Facility for Accelerated Service Testing (FAST), tie center bending strains evaluated on the same tie type under 315-kip GRL vehicles measured up to 40 percent of the calculated cracking strain of the tie. In-service tie center bending strains for the CXT tie under a 286-kip HAL train measured up to 49 percent of the tie's calculated cracking strain, while the KSA ties measured up to 52 percent of its calculated design cracking strain in revenue service. It is likely that variations between revenue service and FAST test results are due to a difference in tie support conditions.

The AAR will continue to monitor the concrete tie center bending strains and tie conditions in an attempt to capture the influence of HAL traffic on tie fatigue life and performance.

Suggested Distribution:

☐ Research & Development
☐ Maintenance of Way
☐ Maintenance Planning
☐ Track Maintenance

Association of American Railroads
Railway Technology Department
September 1997

TECHNOLOGY DIGEST
September 1997

INTRODUCTION AND CONCLUSIONS

The introduction of heavy axle load (HAL) traffic (286-kip gross rail weight cars) on revenue service lines is being evaluated through the Association of American Railroads' (AAR) HAL Revenue Service Monitoring program. The program was initiated in 1992 to monitor track environments not found at the Transportation Technology Center's (TTC) High Tonnage Loop (HTL).

The maximum concrete tie center bending strains measured on three concrete tie designs—Burlington Northern (BN100), KSA, and CXT—show an increase of 15 to 25 percent due to the increase in axle loads. However, the results to date also show that HAL effects may be greatly influenced by the concrete tie design stresses.

Monitoring the influence of HAL traffic on tie performance was necessary due to the projected long life and slow deterioration rate of the concrete tie; no rail seat abrasion was observed at the test sites. Concrete tie bending strains may be used to assess the influence of increased axle loads on tie life. Concrete tie tests on two revenue service lines are measuring concrete tie bending strains to provide the industry with an early indication of any service life changes.

TEST SITES

Two locations on revenue service mainlines were selected to measure concrete tie bending strains under HAL traffic. The first is located on CSX Transportation's James River Subdivision near Eagle Rock, Virginia, while the second is located on Burlington Northern Santa Fe's (BNSF) Spanish Peaks subdivision near Mayne, Colorado. Both test sites receive loads and empties — mostly unit coal traffic and some mixed freight. Both are located on 6-degree curves.

INSTRUMENTATION AND DATA COLLECTION

Four BN100 Lonestar concrete ties were instrumented on the BNSF site. Four ties each of the KSA and CXT tie designs were instrumented on the CSX site. Three strain gages were installed on each tie to measure concrete tie bending strains under traffic. One gage was applied to the top center of the tie while the remaining two gages were applied to one side of the tie directly under the rail seat areas, approximately 3/4-inch below the tie chamfer. Lateral and vertical rail circuits were also installed to identify the wheel loading associated with the measured concrete tie bending strains.

Data for both locations has been collected during one week each year for the last three years. The number of trains sampled during each data collection varied with traffic conditions and test site. A database including dynamic vertical and lateral rail forces and tie bending strains was generated during each measurement cycle. Car weight was determined by adding the eight vertical wheel loads of each car; an average car weight per train was then calculated. Trains with average car weights below 278,000 pounds were classified as conventional trains while those above 278,000 pounds were classified as HAL trains (278,000 is slightly over the midpoint between 263,000 and 286,000; thereby taking into account over-loaded 263-kip cars and under-loaded 286-kip cars).

Concrete tie bending strains were counted using the rainflow technique commonly used in fatigue studies. A total of four cycles are counted with the passing of two adjacent trucks for two coupled cars. Three of the cycles are smaller and reflect the strains generated by the four individual axles, while the large cycle reflects the strains generated by the two adjacent trucks.[1] Exhibit 1 illustrates the cycles generated by the wheels and by the two adjacent trucks. Because increases in bending strains in the rail seat area were so small, only tie center bending strains will be discussed herein.

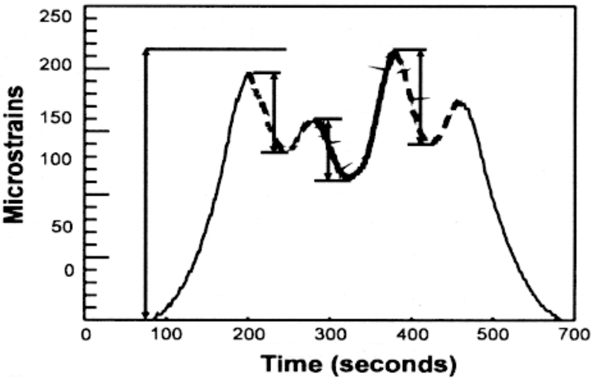

Exhibit 1. Strain Response Under Adjacent Truck of Coupled 36-ton Axle Load Cars

RESULTS

During the four years of data collection, only two HAL trains were captured over the BN100 concrete ties at the BNSF test site due to the slower rate of HAL traffic introduction. At the CSX test site, over 20 HAL trains were captured over the KSA and CXT ties. The histogram in Exhibit 2 shows the center bending strains measured over four KSA ties under a conventional train and a HAL train. The bimodal distribution for both trains shows the response to the individual axles and to a pair of adjacent trucks. The histogram shows the increase in tie center bending caused by an increase in axle loads.

Exhibit 3 shows a comparison of tie center bending strains measured under HAL trains for the three different tie designs.

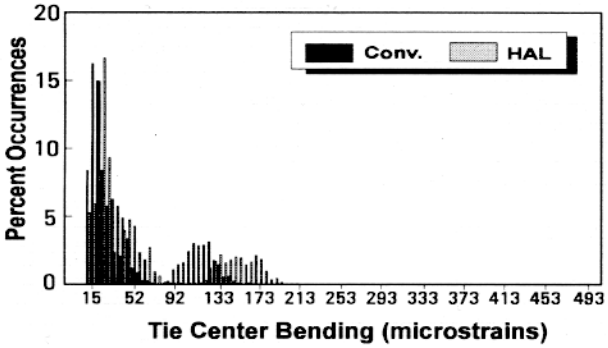

Exhibit 2. Histogram of Center Bending Strains

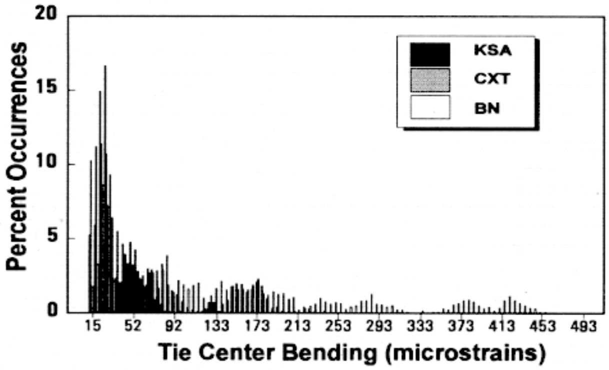

Exhibit 3. Histogram Under HAL Trains for Three Tie Designs

The CXT and KSA tie designs measured on the CSX test site show similar tie center bending strains. The strains under the KSA are slightly lower, which is most likely due to its larger size. However, the BN100 ties show significantly higher tie center bending strains. These differences in magnitude may be due to the tie size, ballast tamping conditions, and support conditions. While the KSA and CXT tie designs have about the same depth at the center of the tie and are of similar length, the BN100 tie is shorter and is more shallow at the tie center.

Tie support conditions appear to influence the measured tie center bending strain. Bending strains for four instrumented BN100 ties measured under one 286-kip train are shown in Exhibit 4. Because bending strains below 100 microstrains may have minimal, if any, influence on the tie, only data above 100 microstrains has been used in the analysis and graphs.

The four ties measured were within 24 feet of each other; there was no apparent difference in the track structure over this short zone. The significant difference in the measured tie center bending strains is most likely due to the support condition under the ties. The difference in center bending between the four ties was evident under all trains sampled. This indicates track support conditions were the most likely contributing factor to the tie response. The highest tie center bending strain generated by the HAL train shown in Exhibit 4 is slightly under 500 microstrains.

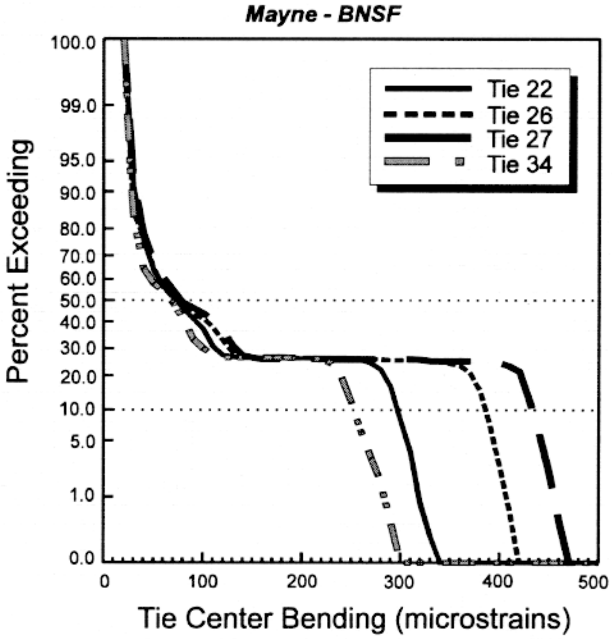

Exhibit 4. Bending Strains Under of HAL Train Measured on Four BN Ties

Tie support conditions also appear to influence the measured tie center bending strains on the KSA and CXT tie designs. However, the difference between ties appears to be significantly less. This may be due to more consistent tie support conditions and/or larger tie size.

Exhibit 5 shows the bending strains measured under the same HAL train over four ties of both designs. The highest tie center bending strain measured under this HAL train is between 180 and 250 microstrains—well below the cracking strain for both tie designs.

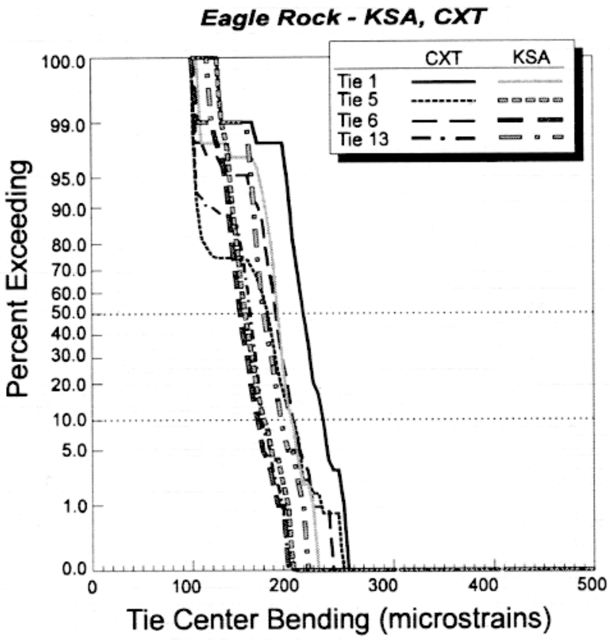

Exhibit 5. Bending Stains Measured Under a HAL Train

A relative comparison of the BN100, KSA, and CXT tie designs is shown in Exhibit 6. The data reflects the median bending strains, above 100 microstrains, measured under one conventional train and one HAL train. The increase in tie center bending strains caused by the increase in axle loads under all three tie designs varied between 15 and 25 percent. The graph in Exhibit 6 clearly depicts the difference in the measured bending strains between the tie designs. There is a difference of 30 to 40 percent for the BN100 tie design, compared to the CXT and KSA tie designs. The difference relative to tie design is evident. The bending strains are comparable for the CXT and KSA tie; however, the BN100 tie exhibits considerably higher bending strains.

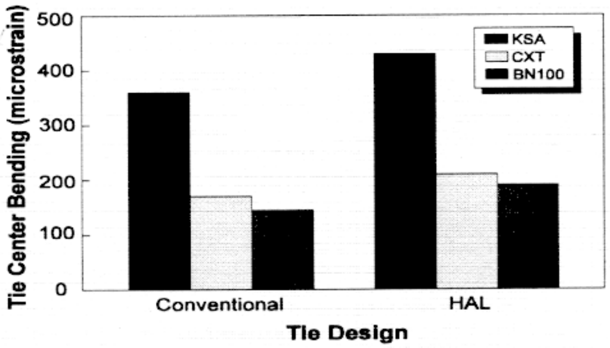

Exhibit 6. Tie Bending Strains at the 90th Percentile

Tie center bending strains on the BN100 ties measured up to 83 percent of the calculated cracking strain in revenue service, while the strains measured on the same tie type on the FAST track only measured 40 percent of the tie's calculated cracking strain. Tie center bending strains for the CXT tie under a 286-kip train measured up to 49 percent of the tie's calculated cracking strain in revenue service while the KSA tie measured up to 52 percent. None of the measured bending strains exceeded the calculated cracking strain for the three tie designs; however, the peak strains on the BN100 are approaching the calculated design cracking strain. Differences between revenue service and FAST results for the BN100 ties are most likely due to differences in tie support conditions.

REFERENCES

1. Gage, Scott E. and Duane E. Otter, "Preliminary Results of Concrete Tie Strain Measurements at FAST," Association of American Railroads, *Technology Digest*, TD-022, October 1995.

Note: Contact Carmen Trevizo (719) 584-0560 or Rafael Jimenez (719) 584-0691 with questions or comments regarding this document. E-mail:carmen_trevizo@aar.com or rafael_jimenez@aar.com

Disclaimer: Preliminary results in this document are disseminated by the AAR for information purposes only and are given to, and are accepted by, the recipient at the recipient's sole risk. The AAR makes no representations or warranties, either express or implied, with respect to this document or its contents. The AAR assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential or any other kind of damage resulting from the use or application of this document or its content. Any attempt to apply the information contained in this document is done at the recipient's own risk.

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON, D.C.,20001