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ESTIMATED EFFECTS OF 286,000-POUND CARS ON A PIN-CONNECTED TRUSS

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TD 96-018

Summary
Revenue service tests were conducted on a 165-foot pin-connected, open-deck, through-truss bridge. Association of American Railroads (AAR) researchers measured axial, bending, and shear strains of key members, as well as vertical wheel loads due to passing trains. Preliminary test findings show:

- As compared to conventional (263,000-pound nominal gross rail load) cars, the increase in fatigue damage resulting from the heavy axle load (HAL) (286,000-pound nominal gross rail load) cars is two to three times higher than the axle load increases for some members of the bridge.
- The stringers, floor beams, and hangers suffer the highest fatigue damage, because these members experience a high number of stress cycles. Fatigue damage rates in these members increase by 14 to 19 percent when HALs are operated on the structure. The other members of the bridge, like the lower chord and diagonals, suffer less fatigue damage. This finding has revealed an opportunity to extend the fatigue life of the structure by replacing just the fatigue-prone elements, such as the floor system and the hangers.
- Maximum stresses in the bridge were well within the design stress limit for both conventional and HAL cars. The average maximum live-load stresses under HAL cars were higher than stresses under the conventional cars by 6 to 8 percent.
- The average HAL car weight is about 7 percent heavier than the average car weight measured for conventional cars.

This study is being conducted to evaluate fatigue behavior and to develop cost-effective techniques for handling HAL traffic on steel bridges.

Suggested Distribution:
☐ Maintenance of Way
☐ Research and Development
☐ Maintenance Planning
☐ Bridge Maintenance

Association of American Railroads
Research and Test Department
September 1996

TECHNOLOGY DIGEST
September 1996

INTRODUCTION AND CONCLUSIONS

Increasing freight car axle loads are causing some railroad bridge components to approach the end of their fatigue lives at an accelerated pace. Steel truss bridges are particularly affected, because many of the fracture critical members of a truss (floor systems, hangers, etc.) are especially prone to high fatigue damage. Hence, the Association of American Railroads (AAR) initiated a research program to evaluate the effects of heavy axle loads (HALs) on the fatigue behavior of railroad bridges and to develop methods to extend their lives.

A test program was initiated in 1993 to evaluate the load environment and the effects of heavy axle loads, and to determine the response of common steel bridges to these loads. The objective was to collect bridge load and response data under conventional (263,000-pound cars) and HAL (286,000-pound) load environments over time, as more and more HAL cars are introduced in revenue service. Under this program, two bridges, a 165-foot pin-connected open deck through truss and a 65-foot ballasted deck through-plate-girder bridge, have been instrumented to determine their load environment and response to heavy axle loads. This digest summarizes the results of the testing on the pin-connected truss.

The bridge was instrumented to measure the vertical rail load at two locations on each rail; axial strains at several key truss members, and bending stresses in the floor system. A data-acquisition system recorded strains and wheel loads as revenue trains crossed the bridge. The bridge schematic is shown in Exhibit 1.

The strain data for various members of the bridge was analyzed to determine the maximum live-load stress, the stress range, and the number of stress cycles. From these data, the fatigue life consumed per 10 million gross tons (MGT) of traffic was calculated. The maximum live load stresses in the truss members ranged from 4 ksi to 7.9 ksi for conventional loads and from 4.3 to 8.5 ksi for HAL loads.

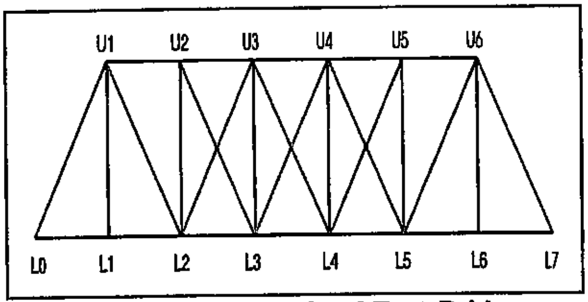

Exhibit 1. Schematic of Test Bridge

Of the various instrumented members, the first diagonal (U1-L2) had the highest maximum stress. The stress cycles in various members were calculated using a rainflow counting algorithm. Based on the number of cycles and the fatigue category (Category C for the lower chord, Category D for the other members), as specified in Chapter 15 of the AREA manual, the fatigue damage for the various instrumented components was computed.

As expected, the fatigue damage rates resulting from HAL trains were higher than those of the conventional trains. This observation is not true in every case, because many other factors (such as the number of axle loads and their spacings) affect the evaluation of fatigue damage.

The reliability of the measurements was verified by using the Root Mean Cube (RMC) values calculated from the stress cycles, which were compared to theoretically calculated values. RMC is a stress parameter representing the cubic mean of the stress ranges.

CAR LOADINGS

Vertical wheel load measurements were used to evaluate the number of trains, their gross weights and axle spacings. The trains were classified as conventional or HAL trains based on average car weight for the train. Exhibit 2 shows the distribution of car weights in typical conventional and HAL trains.

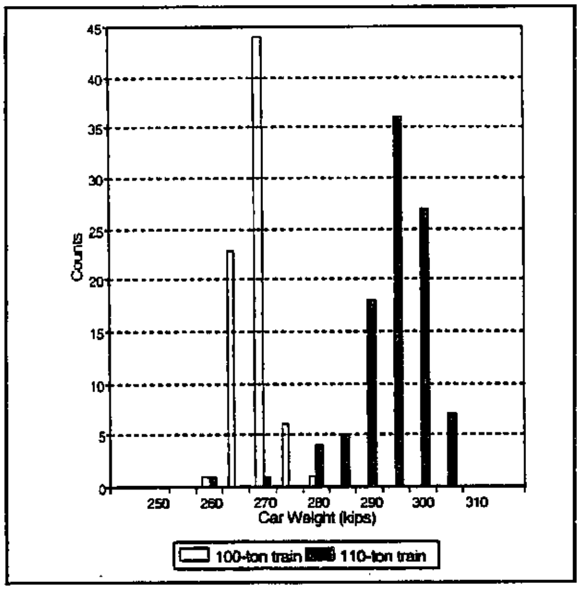

Exhibit 2. Car Weight Distributions

Data was recorded from 58 loaded trains. Forty-eight of these were conventional trains and 10 were HAL trains. The average dynamic car weights measured were 276.3 kips per car (34.5 tons/axle) for the conventional trains and 296.2 kips per car (37 tons/axle) for the HAL trains. The measured weights, which include some dynamic component, may be higher than actual static car weight. The average measured dynamic car weight for the HAL trains was approximately 7 percent higher than the average measured dynamic car weight of conventional trains.

MAXIMUM STRESSES

The maximum stress a member experiences is an indication of the rate of consumption of fatigue life. A bridge rating can be evaluated using the maximum stress values its members experience when a train passes. In order to determine the necessity or feasibility of any strengthening or rehabilitation procedure, it is necessary to know the maximum stress in various members of a bridge for a given set of loads. AAR calculated the maximum stress values for each train pass and the average of these maximum values resulting from conventional and HAL trains. The average maximum stress values for members in the south truss and the south stringer are presented in Exhibit 3. Maximum stresses for the HAL trains were 6 to 8 percent higher than maximum stresses for the conventional trains. Since the measured car weights were approximately 7 percent higher for the HAL trains, the increase in maximum stresses is reasonable.

Exhibit 3. Average Maximum Stress (ksi) (South Truss)

	Hanger U1-L1	Diagonal U1-L2	Upper Chord U2-U3	Lower Chord L2-L3	Diagonal U4-L3	Stringer L0-L1	Floor Beam L1-L1
Conventional	6.2	7.9	5.1	4.7	4.0	6.7	5.7
HAL	6.7	8.4	5.4	5.1	4.3	7.2	6.1
% Difference	8	6	7	7	6	8	6

STRESS RANGES

The stress ranges for various critical members were evaluated to calculate the fatigue damage to the members. The stress ranges generated from each passing train were evaluated by counting the resulting number of stress cycles using the rainflow counting algorithm. Each car caused approximately one stress cycle in the hanger, the diagonals, the stringer, and the floor beam. However, each train caused only one major stress cycle in the lower chord. The approximate stress ranges for the hangers, the diagonals, the lower chord, the stringers, and the floor beams are 3.5 ksi, 2.5 ksi, 0.5 ksi, 6.0 ksi and 3.5 ksi respectively.

FATIGUE DAMAGE RATES

One objective of this project was to assess the extent of fatigue damage to various bridge members caused by passing HAL trains on the bridge. Fatigue damage of various members was evaluated using Miner's rule of cumulative fatigue damage. Based on the fatigue categories described in Chapter 15 of the AREA manual, the lower chord member was assigned fatigue category 'C,' while the other members were assigned category 'D.' The fatigue damage was evaluated per 10 million gross tons (MGT) of traffic. Exhibit 4 shows the calculated average fatigue rates for the various bridge members.

Although the increases in damage are higher for the diagonals and lower chord, the floor system members and the hanger are subject to considerably more fatigue damage than the other members. Results show that overall, HAL trains cause more fatigue damage than conventional trains in all members. This is, however, not true in each case, because fatigue damage is dependant not only on the gross weight of the train, but also on factors like the arrangement of cars in a train and the axle spacings.

BRIDGE CONSTRUCTION

The bridge is a pin-connected through truss, with deck plate girder approaches. The truss spans 164 feet 6 inches over the Levisa Fork River on a single-track line operated by CSX Transportation. The bridge, built in 1903, has seven panels of equal length. The three central panels have counter diagonals. The hangers are 30 feet high, and the floor beams span 16 feet 2 inches. The center-to-center spacing of the stringers is 6 feet 6 inches. Traffic on the bridge consists primarily of loaded and empty unit coal trains, with a small percentage of mixed train traffic as well. Total traffic is about 18 MGT per year.

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Exhibit 4. Damage Rates (%) per 10 MGT - South Truss

	Hanger	Diagonal	Lower Chord	Diagonal	Stringer	Floor Beam
100-Ton	0.109	0.0181	0.0032	0.0390	0.457	0.102
110-Ton	0.124	0.0253	0.004	0.0448	0.544	0.116
Differ.(%)	14	40	25	15	19	14