

### ESTIMATED EFFECTS OF 286,000-POUND CARS ON A BALLASTED-DECK, THROUGH-PLATE-GIRDER BRIDGE

by Satya P. Singh and Duane E. Otter

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#### Summary

Tests performed on a 65-foot, ballasted, through-plate-girder steel bridge in revenue service have yielded information that may lead to life-extension techniques for bridges of this type. The bridge studied by the Association of American Railroads (AAR) was instrumented to measure bending and shear strength of key members, as well as vertical wheel loads due to passing trains. The tests are part of AAR's program to evaluate fatigue behavior and to develop effective techniques for handling 286,000-pound heavy axle load (HAL) cars on steel bridges. Preliminary test findings indicate:

- The fatigue life of the bridge structure can be extended by replacing only the fatigue-prone elements of the floor system. The floor beams suffered the highest fatigue damage, the rate being as much as six times higher than that of stringers.
- As compared to conventional 263,000-pound nominal gross rail-load cars, the increase in fatigue damage due to the HAL cars was about three to four times higher than the axle-load increases for some floor-system members of the bridge. When HAL trains were operated on the bridge, fatigue-damage rates increased by 8 to 30 percent in stringers, and by 14 percent in floor beams.
- Among the stringers, the middle stringers showed more fatigue damage than either the north or south stringers.
- The deck plate and deck beams have the effect of distributing axle loads more evenly among the stringers in a panel. The HAL cars appeared to increase loading of the north and south stringers more than the middle stringer in a panel. This resulted in a damage-rate increase of about two to four times more in the north and south stringers compared to the middle stringer.
- Maximum stresses in the bridge floor members were well within the design stress limit for both conventional and HAL trains. The average maximum live-load stresses under HAL cars were higher than stresses under the conventional cars by 3 to 7 percent.

#### Suggested Distribution:

- Bridges & Roadway
- Maintenance of Way
- Maintenance Planning
- Research Development



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Railway Technology Department

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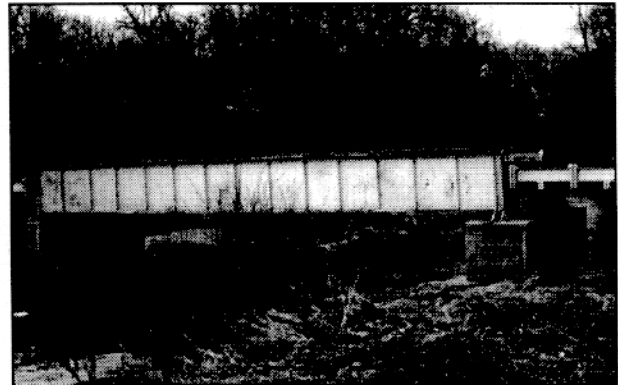


## INTRODUCTION AND CONCLUSIONS

Heavier freight-car axle loads are causing some railroad bridge components to experience fatigue damage at an accelerated pace. The floor system of a bridge is particularly affected, because its members (stringers and floor beams) experience a high number of stress cycles during the passage of a train. Hence, the Association of American railroads (AAR) initiated a research program to evaluate the effects of Heavy Axle Load (HAL) trains 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 to compare the responses of typical steel bridges under conventional and HAL trains. The objective was to collect bridge-load and response data under current load environments over time, as more HAL cars are introduced in revenue service. Under this program, two bridges, a 65-foot, ballasted-deck, through-plate-girder bridge and a 165-foot pin-connected, open-deck, through-truss bridge have been instrumented to monitor their revenue-service loads and responses. This digest summarizes the results of the 1995 tests on the through-plate-girder bridge shown in Exhibit 1.

The bridge was instrumented to measure the vertical rail load at one location on each rail, axial strains at north and south sides of the deck plate, and bending and shear stresses in the floor system. A data

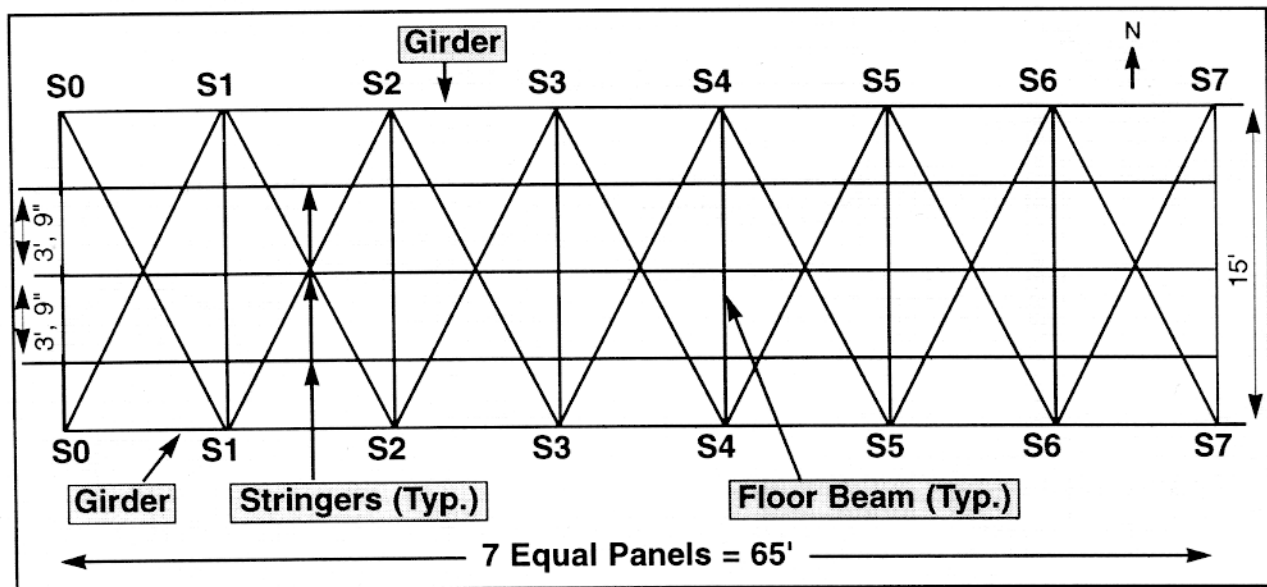


**Exhibit 1. Union Pacific's Through-Plate-Girder Bridge near Frankfort, Kansas**

acquisition system recorded strains and wheel loads as revenue trains crossed the bridge. The bridge schematic is shown in Exhibit 2.

The strain data for various members of the floor-system was analyzed to determine maximum live-load stresses, stress ranges 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 stringers ranged from 4.44 ksi to 4.95 ksi for conventional loads, and from 4.69 ksi to 5.22 ksi for HAL loads. Similarly, stresses at the center-of-floor beams were from 5.46 to 5.54 ksi for conventional loads, and 5.76 to 5.88 ksi for HAL loads.

The stress cycles in various members were calcu-



**Exhibit 2. Schematic of Test Bridge**



lated using a "Rainflow Counting" algorithm. Based on the number of cycles and fatigue categories (Category 'C' for stringers and Category 'D' for the floor beams), as specified in Chapter 15 of the American Railway Engineering Association (AREA) manual, the fatigue damage for the various instrumented members was computed using the Miner's rule of cumulative damage. As expected, the fatigue damage rates under HAL trains were higher than those under conventional trains. This observation may not be true in every case, because many other factors (such as arrangement of loaded and empty cars, and the axle spacings) affect the evaluation of fatigue damage.

#### FATIGUE DAMAGE RATES

The most important objective of this project was to assess the extent of fatigue damage to various bridge members caused by the HAL traffic. Using Miner's rule of cumulative damage as it applies to stringers and floor beams (Category "C" for stringers and Category "D" for floor beams from Chapter 15 of the AREA manual), the fatigue damage to these members was evaluated and the percentage of fatigue damage was calculated per 10 MGT of traffic. Exhibit 3 shows the calculated average fatigue rates for the stringers and floor beams.

The floor-beam fatigue rates, on average, are about six times higher than the stringer fatigue rates. On the other hand, the increase in south stringer S2-S3 fatigue-damage rate is more than twice the floor-beam rates under the HAL traffic. This appears to occur due to the increased loading of the south stringers under the HAL trains. Overall, HAL trains cause more fatigue damage than the conventional trains in both the stringers and floor beams.

#### STRESS RANGES

The stress cycles generated from each passing train were obtained by counting the resulting number of stress cycles in various stress ranges using the Rainflow Counting method. Each car caused approximately one stress cycle in the stringer and floor beam. The majority of stress cycles were between 3 and 5 ksi for stringers, and 4 and 6.5 ksi for the floor beams.

#### CAR LOADINGS

Vertical wheel-load measurements were used to evaluate the number of cars, their gross weights and axle spacings. The trains were classified as conventional or HAL trains based on the preponderance of loaded 100-ton or 110-ton cars in the train. Exhibit 4 shows the distribution of car weights in typical conventional and HAL trains.

Data from 72 loaded trains was recorded in 1995. Fifty-six of these were conventional trains, and 16 were HAL trains. The average dynamic car weights measured were 261.1 kips per car (32.6 tons/axle) for the conventional trains and 281 kips per car (35.1 tons/axle) for the HAL trains. The measured weights, which include some dynamic components, are probably higher than actual static car weights. The average measured dynamic car weight for HAL trains was about 7.6 percent higher than average measured dynamic car weight of the conventional trains.

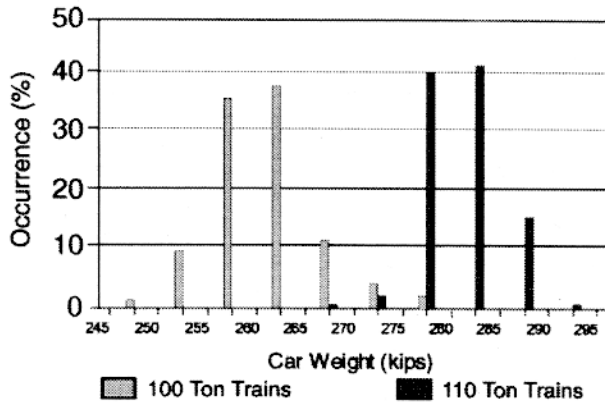
#### MAXIMUM STRESSES

The maximum stress a member experiences is an indication of its load capacity (stiffness and strength), and influences the rate of consumption of its fatigue life. Bridge rating can be evaluated using the maximum stress values its members experience when the

	C.-S. Stringer		C.-M. Stringer		C.-N. Stringer		Floor Beam S3	Floor Beam S4
	S2S3	S3S4	S2S3	S3S4	S2S3	S3S4	Center	Center
Conventional	0.0585	0.0658	0.1230	0.1384	0.0868	0.0713	0.5393	0.5289
HAL	0.0760	0.0786	0.1323	0.1489	0.0988	0.0777	0.6146	0.6005
% Difference	30	20	8	8	14	9	14	14

C. = Center Line, M. = Middle, S. = South, N. = North

Exhibit 3. Damage Rates (%) per 10 MGT — Floor System



**Exhibit 4. Car Weight Distributions**

heaviest train on the line passes over it. 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.

The maximum stress values in the floor-system members, for each train crossing, were measured. The average of these maximum values resulting from the conventional and HAL trains were then calculated.

The average maximum bending stresses for members of the floor system are given in Exhibit 5. As apparent from this exhibit, the maximum stresses for the HAL trains were 3 to 7 percent higher than maximum stresses for the conventional trains.

It also appears that the increase in loading of the south stringers is comparatively more under the

HAL trains. Because the measured car weights were approximately 8 percent higher for the HAL trains, the increase in maximum stresses is reasonable.

**BRIDGE DESCRIPTION**

The bridge is located on the Union Pacific Railroad's Marysville Subdivision near Frankfort, Kansas. The portion of the structure that was tested is the 65-foot, ballasted-deck, through-plate-girder span, which is the main span of the entire 265-foot bridge over Irish Creek. The bridge span tested was converted from an open deck to a ballasted deck in 1957, and was designed for an E49 Cooper loading. The plate girders are 6 feet deep. There are eight 15-foot floor beams dividing the span into seven panels of equal length. In each panel, there are three stringers. Center-to-center spacing of stringers is 3 feet, 9 inches. The track is tangent with no vertical grade, and consists of 133RE continuous welded rail on wood cross ties. The posted speed over the bridge is 70 mph. The line has a traffic density of over 100 MGT per year, and consists of unit trains, intermodal and mixed-freight traffic.

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**Note: Contact Satya Singh at (719) 584-0545 with questions or comments about this document. E-mail: satya\_singh@aar.com**

	C.-S. Stringer		C.-M. Stringer		C.-N. Stringer		Floor Beam S3			Floor Beam S4		
	S2S3	S3S4	S2S3	S3S4	S2S3	S3S4	S. End	Center	N. End	S. End	Center	N. End
<b>Conventional</b>	4.44	4.57	4.78	4.95	4.70	4.52	.36	5.46	.36	.40	5.54	.40
<b>HAL</b>	4.71	4.90	4.98	5.22	4.93	4.69	.38	5.76	.37	.41	5.88	.40
<b>% Difference</b>	6	7	4	5	5	4	6	5	3	3	6	0

C. = Center Line, M. = Middle, S. = South, N. = North

**Exhibit 5. Average Maximum Bending Stress (ksi) — Floor System**

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