TECHOLOGY DIGEST

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Longitudinal Forces in an Open-Deck Steel Bridge

by Joseph A. LoPresti, Duane E. Otter, Daniel H. Tobias,* and Douglas A. Foutch*

Summary

Preliminary analyses of tests conducted on a four-span, 400-foot, open-deck steel bridge indicate the bridge resists a significant percentage of longitudinal forces induced by high-adhesion alternating-current locomotives. These results confirm findings from a similar test conducted on a single-span bridge in 1996[1]. Two locomotives pushing a fully loaded coal train applied tractive forces ranging from about 80 kips to about 175 kips per locomotive to the rail on the bridge during a series of test runs in October 1997 administered by the Association of American Railroads (AAR) and the University of Illinois at Urbana-Champaign. Rail anchoring on the approaches, and hook-bolt conditions on the bridge were varied to determine their effects on the transmission of longitudinal forces into the bridge.

Findings include:

- Longitudinal forces, calculated from measurements, were up to about 220 kips in the 210-foot truss, 110 kips in the 42-foot beam span, and 330 kips in the entire structure.
- Smooth tops on the stringers and beams did not prevent high longitudinal forces from being transmitted into the bridge.
- A higher percentage of the force applied to the two end spans went into those spans than was the case for the two center spans.
- Tightening the hook bolts on the bridge had a greater effect on forces into the spans than loosening anchoring on the approaches.

This is the second test in an AAR-sponsored study of longitudinal forces in bridges. These results will be used to further refine American Railway Engineering and Maintenance of Way Association design guidelines, and to develop methodologies to minimize the adverse effects of longitudinal forces on bridge life and maintenance. They are specific to this bridge. Other bridge types and designs could produce different results. Upcoming tests will examine bridges with different designs and features.

A longitudinal force test on the two-span open-deck plate-girder bridge on the high-tonnage loop at the Federal Railroad Administration's Transportation Technology Center was completed in March 1998. Results will be reported later this year.

*University of Illinois Urbana-Champaign

Suggested Distribution:
o Maintenance of Way
o Structures
o Track Maintenance
o Bridges & Roadway

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INTRODUCTION AND CONCLUSIONS

Preliminary analyses of tests measuring longitudinal force applied by high-adhesion alternating-current (AC) locomotives on a four-span, 400-foot, open-deck steel bridge show that a significant percentage of this force is resisted by the bridge. The primary purpose of the test conducted by the Association of American Railroads (AAR) in conjunction with the University of Illinois at Urbana-Champaign (UIUC) in October 1997 was to measure the longitudinal forces transmitted into the structure by AC locomotives. These locomotives are capable of producing about twice the tractive effort of older direct-current (DC) locomotives. Bridge-component failure and bridge-maintenance problems associated with longitudinal forces applied by DC locomotives have been reported.

These results confirm findings from a similar test conducted in 1996 on a single-span bridge.[1] The 1996 test showed bridge longitudinal forces much higher than 1996 American Railway Engineering Association (AREA) design provisions. Chapters 8 and 15 of the AREA Manual were changed on the basis of the 1996 test. The changes are reasonable in light of the 1997 test but may need further refinement.

TEST SITE DESCRIPTION

The bridge (shown in Exhibit 1) has four spans. From west to east, the bridge comprises a 210-foot through-truss built in 1913, a 107-foot through-truss built in 1919, and steel beam spans of 39 and 42 feet length installed in 1985 to replace timber approach spans. All spans are open deck, with smooth top stringers or beams. The 107-foot truss has one stringer per rail. All other spans have two stringers or beams per rail. None of the spans is skewed. The bridge is located on a single-track main line of the Burlington Northern Santa Fe that spans the Arkansas River in Pueblo, Colorado. It is at the bottom of a long 1 percent uphill grade for eastbound trains.

The timber ties on the bridge deck are on 15-inch centers. Every third tie on the truss spans is hook-bolted to the outside of the stringers. On the beam spans, every tie is hook-bolted to the outer beams. The ties on the bridge have Pandrol e-clips, Pandrol plates, tie pads, and screw spikes. The approach ties have a nominal spacing of 19.5 inches center-to-center. The 20 ties nearest the bridge on each approach also have Pandrol fasteners. On the west approach, the next 43 ties are fully box-anchored with every other tie anchored thereafter. On the east approach, there are 99 fully box-anchored ties, then a grade crossing. New 136 RE continuous-welded rail was installed less than a month prior to testing, and the Pandrol fasteners replaced cut spikes at the same time. There are no guard rails on the bridge.

The conditions described above are referred to as "as-is" and were used for the first series of tests. Two other anchoring conditions were used. For the second condition, all the hook bolts were tightened by the local bridge and building forces according to their standard procedure. For the third condition, the Pandrol e-clips or box anchors were removed from every other tie for 63 ties on the west approach, and 119 ties on the east approach.

INSTRUMENTATION

Longitudinal rail forces at the ends of each span and applied tractive effort read from the cab displays in the locomotives were the primary measurements used in this analysis. Longitudinal displacement transducers and strain gages also were installed at various locations

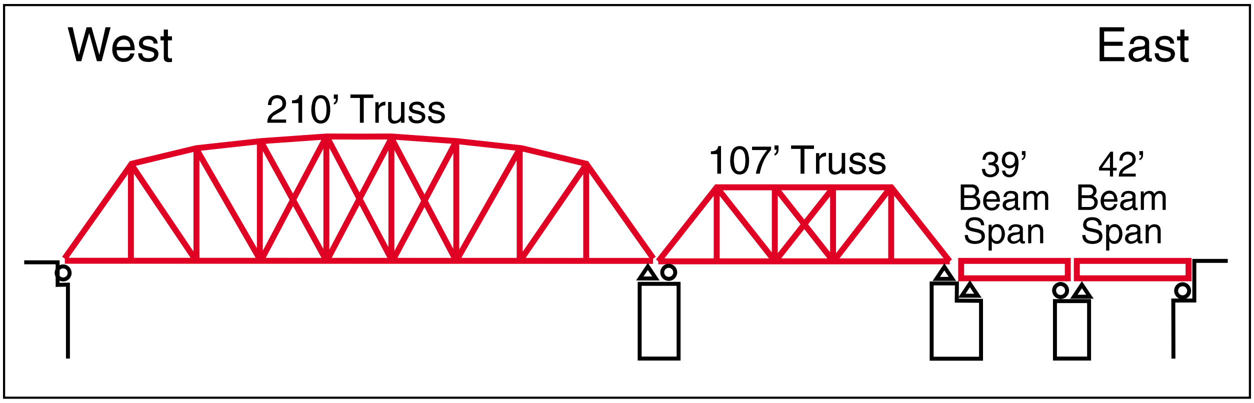

Exhibit 1. 400-Foot Open-Deck Test Bridge

on the bridge and approaches. Those results will be reported later.

TRAIN OPERATIONS

For test purposes, two model SD70MAC locomotives were used to push a typical coal train up the 1 percent grade. The locomotives were operated as closely as possible to their maximum capacity of 180 kips tractive effort per unit for most of the test runs. Tractive effort was kept as constant as possible as the locomotives crossed the bridge. The locomotives were built by the Electro-Motive Division of General Motors, are 74 feet long, and have two, three-axle trucks each.

Complete dynamic-braking runs were not possible, as westbound test trains had to stop short of the Pueblo Junction interlocking, and could not clear the bridge. The maximum dynamic-braking capacity is limited to about 80 kips per unit on these locomotives. Several test runs at reduced tractive effort were used to simulate this condition.

PRELIMINARY TEST RESULTS

Exhibit 2 shows the longitudinal force into each span and the entire bridge for a typical test train as the two pusher locomotives cross the bridge. The “0” distance corresponds to the first axle of the lead locomotive approaching the bridge, and the “575-foot” distance indicates when the last axle of the trail locomotive has cleared. Note that the peak force occurs when the pushers are centered on the bridge. The curve for total longitudinal force into the bridge is quite symmetric, but the curves for longitudinal force into each span are not, due to the variations in span lengths, anchoring, and intermediate support configurations.

Exhibit 3 shows force into each span verses maximum force applied to that span for all tractive-effort runs. The 210-foot span had the largest forces, as expected. More than 200 kips goes into the 210-foot span at the higher tractive-effort levels. The maximum applied tractive effort for the two pushers was about 360 kips. This provided the worst-case condition for the three shorter spans, but for spans longer than about 150 feet, an additional locomotive could put in more force (up to about 400 kips which is the practical drawbar and coupler capacity).

Exhibit 3 also shows that a higher proportion of force goes into the two end spans than into the two interior spans. Both interior spans have a fixed bearing adjacent to each end, while both end spans have an expansion bearing adjacent to one end, and an approach adjacent to the other (see Exhibit 1). It is likely that the fixed bearings provide greater longitudinal restraint than the expansion bearings, or the approaches immediately adjacent to the end spans. The higher proportions of forces measured in the end spans is consistent with this assumption.

Exhibit 4 also shows this, along with the effect of varying anchoring on and off the bridge. Total force into the bridge remained fairly consistent, but tightening the hook-bolts changed the distribution between the spans. Forces in both beam spans increased, decreased in the 210-foot truss, and stayed about the same in the 107-foot truss. Initial hook-bolt conditions varied from span to span. The beam spans had hook bolts on every tie, and the bolts appeared to be looser than on the trusses, which had hook-bolts on every third tie. The variation in anchoring conditions on the approaches had only minor influences on the longitudinal forces carried by the four spans. This is to be expected on bridges significantly longer than the locomotives applying the trac-

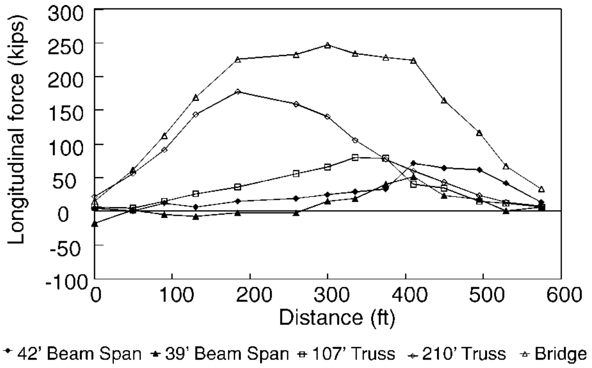

Exhibit 2. Typical Longitudinal Force in Bridge as Locomotives Cross Bridge

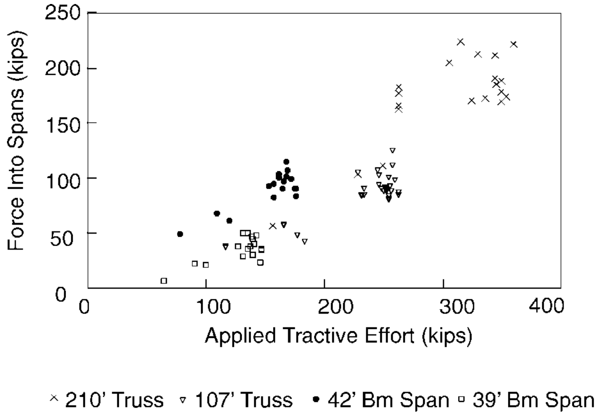

Exhibit 3. Measured Longitudinal Force into Each Span vs. Applied Tractive Effort

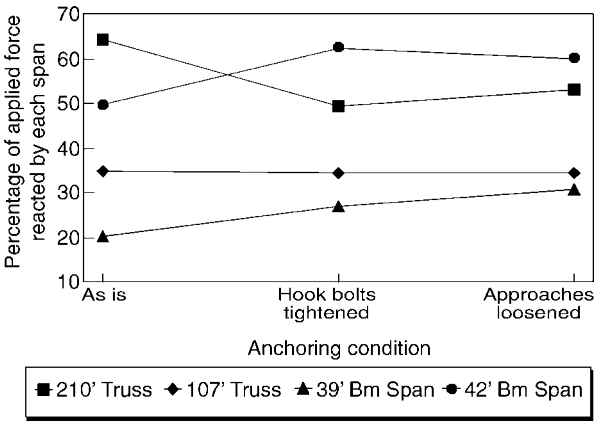

Exhibit 4. Longitudinal Force into Each Span for Various Anchoring Conditions

tive effort.

Exhibit 5 compares maximum measured forces to the 1997 AREA guidelines, and also shows the applied vertical load from the two SD70MAC locomotives (415 kips is nominal locomotive weight), vertical loads from Cooper E-80 design loading, and measured longitudinal force as a percentage of applied vertical loading.

The 1997 AREA Chapter 15 provision 1.3.12.a stating "The longitudinal force from trains shall be taken as . . . the force due to traction equal to 25% of the weight of the regular E-80 axle configuration without impact" is quite conservative for the interior spans, but less so for the end spans. A recommendation based on span and bridge length might be simpler and better.

These results will be used to further calibrate a longitudinal force analytical model developed by UIUC in conjunction with the AAR. They will also be provided to the appropriate American Railway Engineering and Maintenance-of-Way committees. They are valuable in the understanding of longitudinal forces in bridges; however, other bridge types and designs could produce different results.

ACKNOWLEDGMENTS

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REFERENCES

1. Otter, D.E., LoPresti, J.A., Foutch, D.A., Tobias, D.H., "Longitudinal Forces in an Open-Deck Steel Deck Plate-Girder Bridge," Association of American Railroads Technology Digest No. TD96-024, Association of American Railroads, Nov. 1996.

Note: Contact Joseph A. LoPresti at (719) 584-0589 or Duane E. Otter at (719) 584-0594 with questions or comments about this document.

E-mail: **joseph_lopresti@ttci.aar.com**
duane_otter@ttci.aar.com

Web site: **www.ttci.aar.com**

Span	Maximum Measured Force	1997 AREA Guidelines (kips)	Vertical Load on Span (kips) Two SD70MAC Locomotives	Vertical Load on Span (kips) Cooper E-80 Locomotives	Measured Force as % Applied Vertical Load
210-foot truss	223	284	830	1,136	27
107-foot truss	123	284	623	1,136	20
39-foot beam span	49	119	346	476	14
42-foot beam span	113	132	415	528	27
Entire bridge	330	284	830	1,136	40

Exhibit 5. Comparison of Maximum Measured Forces to 1997 AREA Guidelines

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