TECHNOLOGY DIGEST

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LONGITUDINAL FORCES IN A SINGLE-SPAN, BALLASTED-DECK, PLATE-GIRDER BRIDGE

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Summary

Preliminary analysis of test results indicates a 60-foot single-span, ballast-deck, plate-girder steel bridge resists a significant portion of longitudinal forces induced by high-adhesion alternating-current locomotives. A test train consisting of 117 fully loaded coal cars with three SD70MAC locomotives at the east end, and two SD70MACs at the west end, applied tractive effort and dynamic braking ranging from about 80 kips to about 165 kips per locomotive to the rail on and near the bridge.

The primary purpose of the test conducted by Transportation Technology Center, Inc. (TTCI) in December 1998 was to measure the longitudinal forces transmitted to the structure by AC locomotives. Instrumented bridge bearings were used to measure longitudinal forces absorbed by the bridge, perhaps the first time this type of equipment has been used to measure longitudinal forces in a railroad bridge.

Results from this test on a ballasted deck bridge support and expand upon previous findings from similar tests conducted on open-deck steel bridges.[1,2,3]

Findings from these most recent tests include:

- Longitudinal forces up to about 115 kips were measured in the bridge.
- Ballast appears to carry little longitudinal force from bridge.
- Longitudinal force guidelines for open-deck bridges might also be appropriate for ballast-deck bridges.
- Consideration should be given to revision of the interim American Railway Engineering and Maintenance of Way Association (AREMA) design guidelines allowing reductions in design longitudinal load for short-span, ballast-deck bridges.

These findings will be used to refine the provisions in the AREMA Manual. This testing was conducted as part of the Association of American Railroads' strategic research initiative on bridges.

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Work performed by TTCI Transportation Technology Center, Inc.
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INTRODUCTION AND CONCLUSIONS

Transportation Technology Center, Inc. conducted longitudinal force testing on a Burlington Northern Santa Fe (BNSF) single-span, ballast-deck, plate-girder bridge during December 1998. The purpose of this testing was to measure the portion of locomotive tractive effort or dynamic braking that is absorbed by the bridge, as well as the portion carried off the bridge by the rails and the ballast. This is the fourth test in an Association of American Railroads-sponsored study of longitudinal forces in bridges. It is the first test of a ballasted-deck bridge.

While previous tests used an indirect method to determine longitudinal forces resisted by the bridge, this test measured bridge longitudinal forces directly by using custom-designed force-measuring bridge bearings. The instrumented bearings were designed, fabricated, and calibrated by TTCI, and are believed to be the first of their type to be used to measure longitudinal forces in a railroad bridge. A 16,000-ton train consisting of 117 fully loaded coal cars with three SD70MAC locomotives at the east end, and two SD70MACs at the west end, applied up to 165 kips of tractive effort, and up to 80 kips of dynamic braking effort to the rail on the bridge. Preliminary test results are shown in the summary.

TEST-SITE DESCRIPTION

The bridge is a 60-foot, single-span, ballast-deck, plate-girder bridge on a BNSF single track mainline over the North Fork of San Francisco Creek near Barela, Colorado. The structure was built around 1919 as an open-deck bridge. It was converted to a ballast deck in the early 1980s. Track consists of 136-pound rails on concrete ties with Safelok fasteners. Tie spacing is at two-foot centers. Track is tangent over the bridge. Grade is about 1 percent on either side of the bridge. The grade runs uphill from east to west, while normal loaded traffic runs from west to east. Under normal traffic, it is not unusual to have heavy dynamic braking over the bridge (see Exhibit 1).

Exhibit 1. BNSF Bridge at Barela, Colorado

TRAIN-OPERATION MEASUREMENTS

Tractive effort was monitored during uphill runs from east to west, and dynamic braking was monitored during downhill runs from west to east. Tractive effort and dynamic brake force readings were taken from the displays in the locomotive cab at both ends of the train as the locomotives crossed the bridge. A total of seven tractive-effort runs and eight dynamic-braking runs were made with the test train. A final dynamic-braking run utilizing a passing revenue train was made.

MEASUREMENTS/INSTRUMENTATION

In previous tests on open-deck bridges, the only available paths to transfer longitudinal forces from the bridge to the surrounding ground were the rails and the bridge bearings. Force in the bridge was determined indirectly by measuring the longitudinal force in the rails. This rail force was then subtracted from the applied tractive effort or dynamic braking (as read from the locomotive-cab display) to infer the amount of longitudinal force absorbed by the bridge.

In this case the ballast provided an additional potential load path for longitudinal forces. For this reason direct measurement of bridge longitudinal force was taken using force-measuring bridge bearings, installed in place of existing bearings, as shown in Exhibit 2. For completeness, force in the remaining load paths was measured as well. Rail force was measured with strain gages

Exhibit 2. Installing Instrumented Bridge Bearings

as in previous tests, and ballast forces were directly measured using earth-pressure cells mounted vertically in the ballast at each end of the bridge. As before, these forces were compared to applied tractive effort or dynamic braking as read from the cab display. Primary instrumentation included the following:

- Strain-gage circuits for longitudinal rail forces on the bridge and approaches.
- Instrumented bridge bearings at each end of each girder (Exhibit 2).
- Earth-pressure cells at both ends of bridge.
- Standard, locomotive installed, tractive-effort instrumentation.

Vertical forces and longitudinal deflections were also monitored.

PRELIMINARY TEST RESULTS

This test indicates that, as in previous tests, a significant amount of locomotive tractive effort is resisted by the bridge. Exhibit 3 shows bridge longitudinal forces as measured by instrumented bearings. Note that a maximum force of about 117 kips was measured at the bearings with about 140 kips applied tractive effort. A time history of the net force absorbed by the bridge for a particular test train pass is included in Exhibit 4.

Exhibit 3 also indicates that the proportion of the longitudinal forces applied to a span and absorbed by the bridge is higher for the end of the train with three locomotives than for the end with two locomotives. With three locomotives near the bridge, more force is being applied to the rail on the approaches near the span. It is possible that some of this force is transferred onto the span through the rail, or that the longitudinal resistance provided by the approaches is reduced due to the presence of applied longitudinal loads. A similar effect was observed during the 1998[3] test of a two-span bridge at FAST.

Bridge longitudinal forces measured by the instrumented bridge bearings are almost identical to those calculated by subtracting rail force from applied force (see Exhibit 5). This indicates that the ballast carries a negligible amount of longitu-

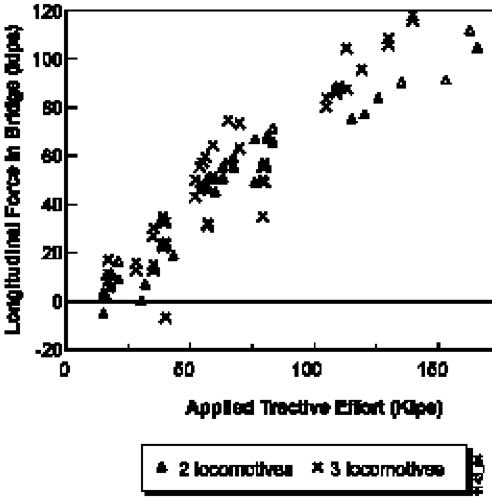

Exhibit 3. Longitudinal Force from Instrumented Bearings

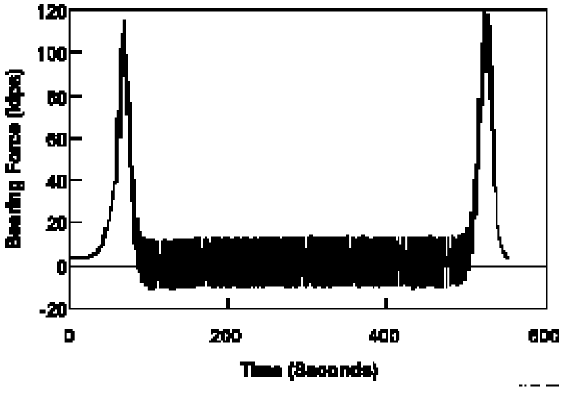

Exhibit 4. Net Force In Bridge from Instrumented Bearings (Time History)

dinal force from the bridge. This result is supported by the very small pressures measured by the ballast pressure cells. Exhibit 6 shows an estimate of ballast forces based on the measured ballast pressure. This test indicates that longitudinal force guidelines for open deck bridges might also be appropriate for ballast deck bridges.

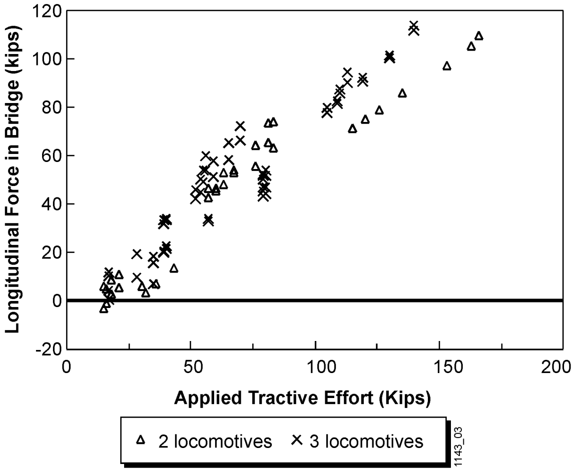

Exhibit 5. Longitudinal Force from Instrumented Rails and Locomotives

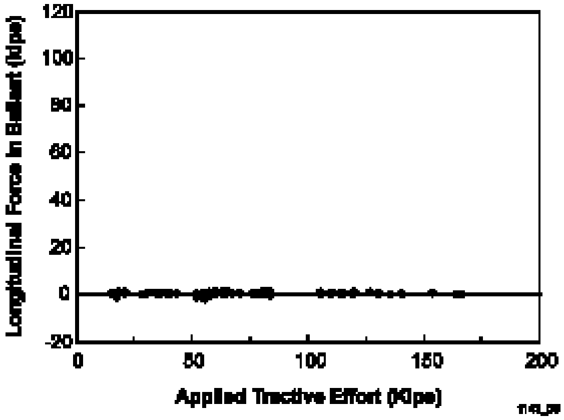

Exhibit 6. Longitudinal Force in Ballast from Earth-Pressure Cells

The 1997 American Railway Engineering and Maintenance of Way Association (AREMA) design guidelines allow design longitudinal force to be halved for bridges less than 200 feet with spans less than 50 feet, based on the assumption that the ballast would carry a large portion of longitudinal force to the abutments. In light of the results of this test, consideration should be given to revision of these guidelines.

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1. Otter, D.E., LoPresti, J.A., Foutch, D.A., and 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, November 1996.
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3. LoPresti, J.A., and Otter, D.E., “Longitudinal forces in a Two-span Open-Deck Steel Bridge at FAST,” Transportation Technology Center, Inc., Technology Digest No. 98-020, Association of American Railroads, August 1998.

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