TECHNOLOGY DIGEST

Timely Technology Transfer — 98-020

Longitudinal Forces in a Two-Span Open-Deck Steel Bridge at FAST

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Summary

Preliminary analysis of tests on a two-span, 121-foot, open-deck, deck-plate-girder bridge indicate that roughly 35 to 75 percent of the longitudinal force applied by high-adhesion alternating-current locomotives is resisted by this bridge. These locomotives are capable of producing about twice the tractive effort of older direct-current locomotives. Some railroads have experienced bridge-component failure and bridge-maintenance problems associated with longitudinal forces. The results from this test are similar to those from tests conducted on a single-span, open-deck bridge in 1996,[1] and a four-span, open-deck bridge in 1997.[2]

In this test, two SD90MAC locomotives, pushing or pulling 39 loaded gondola cars (39-ton axle load) and seven braking locomotives, applied tractive forces ranging from about 50 to 140 kips per locomotive to the rail on the bridge at the Facility for Accelerated Service Testing at the Federal Railroad Administration's Transportation Technology Center. These test runs were administered by Transportation Technology Center, Inc., in March 1998.

Findings include:

- Longitudinal forces up to about 76 kips in the 65-foot span, 96 kips in the 56.5-foot span, and 140 kips total in the bridge were measured.
- The amount of longitudinal force applied by the locomotive wheels that are just off the ends of the spans has a significant effect on the amount of force going into the spans.
- Smooth interface between ties and girders did not prevent high longitudinal forces from being transmitted into the bridge.

This is the third test in an Association of American Railroads-sponsored study of longitudinal forces in bridges. The Federal Railroad Administration cooperatively sponsored certain safety-related aspects of this test. These results will be used to further refine interim guidelines for the American Railway Engineering and Maintenance of Way Association. Other bridge types and designs could produce different results.

Suggested Distribution:

- ❑ Maintenance of Way
- ❑ Bridges & Roadway
- ❑ Track Maintenance
- ❑ Structures

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INTRODUCTION AND CONCLUSIONS

Preliminary analysis of tests on a two-span, 121-foot, open-deck, deck-plate-girder, steel bridge indicate that roughly 35 to 75 percent of the longitudinal force applied by high-adhesion alternating-current (AC) locomotives is resisted by the bridge. The primary purpose of the test conducted by the Transportation Technology Center, Inc., in October 1997, was to measure the longitudinal forces transmitted into the structure by AC locomotives. The provisions of Chapters 8 and 15 of the 1997 American Railway Engineering Association (AREA) Manual regarding longitudinal forces in bridges were changed as a result of 1996 tests, which were the first longitudinal force bridge tests done with high-adhesion AC locomotives. These results are in general agreement with those from tests conducted in 1996 and 1997.

TEST SITE DESCRIPTION

The bridge (shown in Exhibit 1) has two spans. It was installed at the Federal Railroad Administration's Transportation Technology Center on the High Tonnage Loop in October 1997. Both the 65-foot span and the 56.5-foot span were donated by Conrail. Both are square open-deck, welded-steel, deck-plate-girder spans. The bridge is roughly centered in 225 feet of tangent track that is between two 300-foot spirals into 5-degree curves.

The bridge deck on the spans was built to Conrail specifications. The 10" × 10" oak ties on the bridge deck are on 14-inch centers. There are timber spacer blocks between the ties, and steel spacer bars on top of the ties. Every fourth tie is hook-bolted to the outside of the girders, and the rail is anchored at every second tie (there are anchors at the hook-bolted ties). The tie plates on the bridge are on 3/8-inch pads, and are fastened to the ties with cut spikes. The approach ties are nominally spaced on 19.5-inch centers. The ties on the approaches, spirals, and curves on both ends of the bridge are fully box-anchored. Nearly new 136-pound continuously welded rail is on the bridge and approaches. There are no guardrails on the bridge.

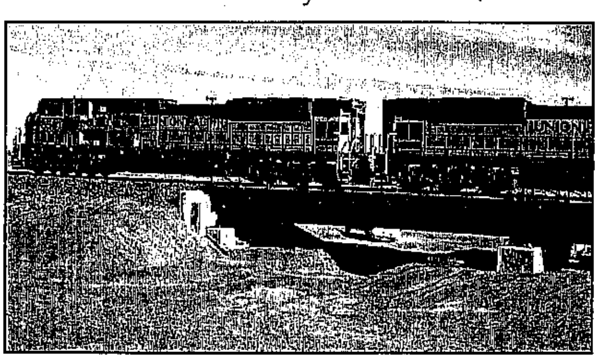

Exhibit 1. Open-Deck Bridge at FAST

The conditions described above were used for the first 13 of 31 test runs. Rail anchors were removed from every other tie for about 250 feet on both approaches for the rest of the runs.

TRAIN OPERATIONS

Two model SD90MAC locomotives pushed or pulled 39 loaded gondola cars (39-ton axle load) and seven direct-current braking locomotives across the bridge. The braking units provided up to about 250 kips of train resistance using dynamic brakes and independent air brakes. The SD90MACs could not be operated at their full capacity since each one is capable of producing about 200 kips of tractive effort. In order to allow high forces to be concentrated on the spans, the lead truck of the lead locomotive, and the trail truck of the trail locomotive were cut out for 21 of the 31 runs. The active trucks were operated as closely as possible to their maximum capacity of 100 kips tractive effort for these test runs. Applied force ranged from 50 kips to 96 kips because limited adhesion reduced the tractive effort available on some runs. Each locomotive applied from 75 kips to 140 kips tractive effort to the bridge during the runs with all four trucks active. Tractive effort was kept as constant as possible as the locomotives crossed the bridge.

PRELIMINARY TEST RESULTS

Exhibit 2 shows force into each span, and the entire bridge versus maximum force applied to the span or bridge for all runs. As expected, there was more force into the bridge than either of the individual spans. About 140 kips went into the bridge when tractive effort applied to the bridge by the two locomotives was about 200 kips. The maximum force into an individual span was 96 kips. Both maximums occurred when all four trucks on the locomotives were applying power.

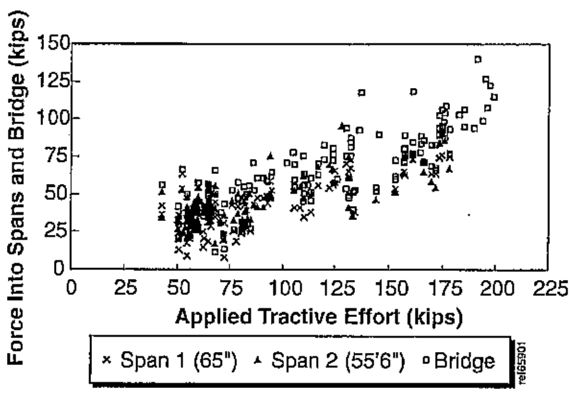

Exhibit 2. Measured Longitudinal Force into Each Span vs. Applied Tractive Effort

Exhibit 3 shows that the ratio of force that goes into a span, versus the force applied directly to that span, is higher when both trucks of both locomotives are active than it is when only one truck per locomotive is active. When all four trucks are active, force can be applied to the rail close to both ends of the span at the same time that force is being applied to the rail on 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.

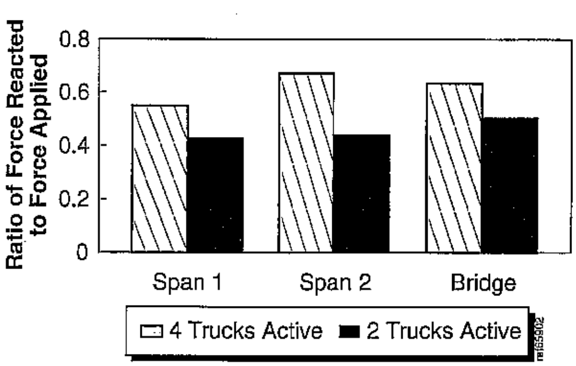

Exhibit 3. Longitudinal Force into Spans as a Proportion of Applied Tractive Effort

Exhibit 4 shows the longitudinal force into the spans and bridge as the two AC locomotives cross the bridge from Span 2 to Span 1. There was one active truck per locomotive for this run. The "0" distance corresponds to the first active truck approaching Span 2, and the "177-foot" distance is when the second active truck has just left Span 1.

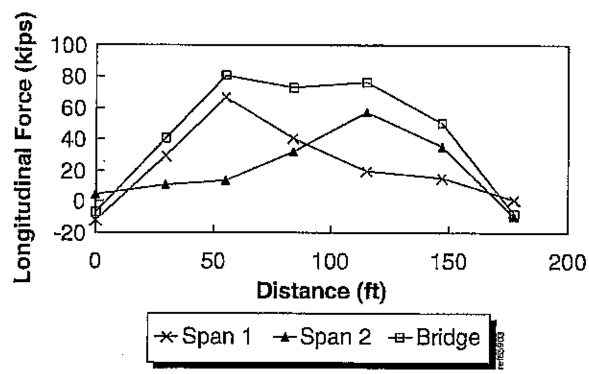

Exhibit 4. Longitudinal Force into Bridge as Locomotives Cross

The force into the bridge is fairly consistent while the two active trucks are on the bridge, but the force into the spans shifts from Span 2 to Span 1 as the locomotives cross the bridge.

Relative displacements between rail and ties, ties and girders, and girders and substructure were measured at several locations. Exhibit 5 shows the maximum measured displacement for all test runs. Also shown for comparison are similar measurements made during the 1996 test of a 50-foot, single-span bridge.[1]

Maximum Displacement (inch)	Rail to Tie	Tie to Girder	Girder to Substructure
Two-span bridge (smooth top girders)	0.26	0.21	0.09
Single span bridge (riveted top girders)	0.15	0.03	0.10

Exhibit 5. Maximum Measured Displacements

The two-span bridge has pads between the tie plates and ties, and girders with smooth tops. The single-span bridge does not have pads between the plates and ties, and its girders have rivets on top which are imbedded into the bottoms of the ties. These are probably the main reasons for the higher displacements on the deck of the two-span bridge. The displacements indicate that this bridge is not as stiff longitudinally as the single-span bridge. The higher proportion of forces in the single-span bridge compared to those in the spans of the two-span bridge (62 to 83 percent vs. 35 to 75 percent under high tractive effort) are consistent with that.

It should be noted that the bridge deck on the two-span bridge is nearly new, and that the rail anchors and hook bolts are still tight. There might have been more movement if the deck had been older. There was no distress noted in any of the bridge members during testing, but a broken hook bolt was found immediately after the test.

The variation in anchoring conditions on the approaches had a minor influence on the longitudinal forces carried by the two spans. The anchors that remained on the approaches (every other tie) were tight against the ties. And, the rail is fully box-anchored beyond the 250-foot zones where every other anchor was removed. Because of this, it is likely that the change in anchoring on the approaches had minimal effect on the overall longitudinal stiffness of the track near the bridge in this case.

Exhibit 6 compares maximum measured forces to the 1997 AREA guidelines, and also shows the applied vertical load from the two SD90MAC locomotives (430 kips is nominal weight for locomotives tested), vertical loads from Cooper E-80 design loading, and measured longitudinal force as a percentage of applied vertical loading.

Span	65-foot DPG	56-foot DPG	Bridge
Maximum Measured Force	76	96	140
1997 AREA Design Load (kips)	182	162	284
Vertical Load on Span Two SD90MACs (kips)	430	430	645
Vertical Load on Span Two Cooper E-80s (kips)	728	648	1,136
Measured Force as % of Applied Vertical Load	18	22	22

Exhibit 6. Comparison of Maximum Measured Force to Various Guidelines

The 1997 AREA Chapter 15 provision on longitudinal loads is conservative for the spans and the bridge. The maximum longitudinal loads were fairly close to 25 percent of the vertical loads applied by the locomotives.

These results will be provided to the appropriate American Railway Engineering and Maintenance of Way Association committees. 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.

2. LoPresti, J.A., Otter, D.E., Tobias, D.H., Foutch, D.A., "Longitudinal Forces in an Open-Deck Steel Bridge," Transportation Technology Center Inc., Technology Digest No. 98-007, Association of American Railroads, April 1998.

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