TECHNOLOGY DIGEST

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LONGITUDINAL FORCES IN AN OPEN-DECK STEEL DECK PLATE-GIRDER BRIDGE

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Summary

The Association of American Railroads (AAR) recently tested a 50-foot open-deck steel deck plate-girder bridge to measure the longitudinal forces induced by high-adhesion AC locomotives. Rail anchoring conditions both on and off the span were varied during the test to determine their effects on the transmission of longitudinal forces into the bridge. Preliminary results show that these forces are much higher than current American Railway Engineering Association (AREA) design recommendations, even at tractive effort levels typical of DC locomotives.

Important findings include:

- Longitudinal forces of nearly 100 kips into the bridge were measured, compared to the current AREA design value of less than 4 kips.
- The maximum measured longitudinal force into the bridge is roughly 25 percent of the locomotive weight applied to the bridge, which is similar to the design guidelines used before 1968.
- The higher the applied tractive effort from the locomotives, the higher the longitudinal force into the bridge.
- The forces into the bridge are reduced when the rails on the approaches are tightly anchored. This allows more of the applied tractive effort to be carried off the bridge through the rails.

This test is the first in an AAR study of longitudinal forces in bridges under new-technology train equipment such as AC locomotives. These results will be used to develop methodologies to minimize the adverse effects of longitudinal forces on bridge life and maintenance. Variations in span length and other bridge features, such as a ballasted deck, may lead to different results.

Suggested Distribution:

- ☐ Maintenance Planning
- ☐ Bridge Maintenance
- ☐ R&D/Test Dept.
- ☐ Maintenance of Way

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INTRODUCTION AND CONCLUSIONS

The Association of American Railroads (AAR) tested a 50-foot open-deck steel deck plate-girder bridge to measure the longitudinal forces induced by high-adhesion AC locomotives. Of concern to industry bridge experts is that these new locomotives, which are capable of roughly twice the adhesion of older series conventional DC locomotives, may put higher longitudinal forces into bridge structures. Higher forces may cause damage to bearings, piers, bracing systems, and other bridge components.

Preliminary analyses show that the forces experienced by the bridge are much higher than current American Railway Engineering Association (AREA) design recommendations. Forces into the bridge of nearly 100 kips were measured during testing. By comparison, the current AREA design loading is less than 4 kips for a 50-foot steel span.

The maximum measured longitudinal force into the bridge is roughly 25 percent of the locomotive weight applied to the bridge, which is similar to the design guidelines used for many older bridges.

TEST SITE DESCRIPTION

Revenue service tests were conducted at Trinidad, Colorado, on the Burlington Northern Santa Fe. The test bridge is located on a 1-percent grade on a line which carries several unit coal trains daily, most of them powered by AC locomotives. The bridge is a single span, built in 1908 for a Cooper E-55 design loading. Rail is continuously welded 132 RE on the bridge and its approaches. The bridge deck has timber ties on 1-foot centers. Every other tie is fastened to the top flange of the girders using an anchor bolt and spring clip. The top flange of the girder has a riveted cover plate along its full length. The rivet heads are imbedded into the deck ties. The west approach has seven timber ties adjacent to the bridge, then concrete ties on 2-foot centers with Safelok fasteners. The east approach has about 55 feet of timber ties, then a turnout which is heavily anchored with Pandrol clips.

INSTRUMENTATION

The bridge girders and bracing, rails, and approach trackage were instrumented to measure strains, forces, and displacements. Key measurements were longitudinal rail forces in both rails at each end of the bridge. The applied tractive effort (whether in traction or dynamic braking) for the AC locomotives was obtained from the cab display. Net force into the bridge was calculated by subtracting the net longitudinal rail force at the ends of the bridge from the tractive effort applied by the locomotive axles on the bridge.

TEST CONDITIONS

During the course of testing, rail anchoring conditions were varied both on and off the bridge to study their effects on bridge longitudinal forces. Four different combinations of anchoring were used:

- Rail on approaches anchored tightly, rail on bridge minimally anchored
- Rail on approaches minimally anchored, rail on bridge minimally anchored
- Rail on approaches minimally anchored, rail on bridge anchored tightly
- Rail on approaches anchored tightly, rail on bridge anchored tightly

For the approaches, minimal anchoring consisted of timber ties without box anchors, and Safelok clips removed from every other concrete tie for 200 feet on the west approach. Tightly anchored approaches consisted of box anchors on all timber ties, and Safelok clips on all concrete ties. For the bridge, minimal anchoring was supplied by the rail clips and anchor bolts in their as-is condition. Tight bridge anchoring consisted of box anchors on each anchored deck tie, as well as tightened rail clips and anchor bolts.

AAR researchers measured forces under revenue service trains in both tractive effort and dynamic braking. The highest forces into the bridge were measured in the tractive effort cases as the locomotives crossed the bridge. The AC locomotives used in the test (Electro-Motive Division model SD70MAC) have a maximum tractive effort per locomotive unit in excess of 150,000 pounds, while maximum dynamic brake effort is limited to about 80,000 pounds. All data presented here is for loaded unit coal trains of approximately 115 cars powered by a three-unit set of six-axle AC locomotives. The highest applied force occurs when a total of six powered axles are on the span, as shown in Exhibit 1.

PRELIMINARY TEST RESULTS

Exhibit 2 shows results from train passes when the approaches were tightly anchored. This is the most common practice for bridges in continuous welded rail territory. As expected, the force into the bridge increases as the tractive effort applied to the rail on the bridge increases. The forces into the bridge for a given applied tractive effort appear to be slightly higher, when the rail on the bridge is tightly anchored, than when the rail on the bridge is minimally anchored. The amount of applied tractive effort varied depending on whether the locomotives were in traction or dynamic braking. Applied tractive effort also varied from one train pass to another due to differences in train handling, train speed, and locomotive performance.

Exhibit 3 shows the results from the train passes when the rail on the bridge was anchored tightly. The highest forces measured during any of the tests were for this condition and minimal approach anchoring. A force into the bridge of nearly 100 kips was measured for an applied tractive effort of about 135 kips. The forces into the bridge are noticeably reduced when the rails on the approaches are tightly anchored. This allows more of the applied tractive effort to be carried off the bridge through the rails.

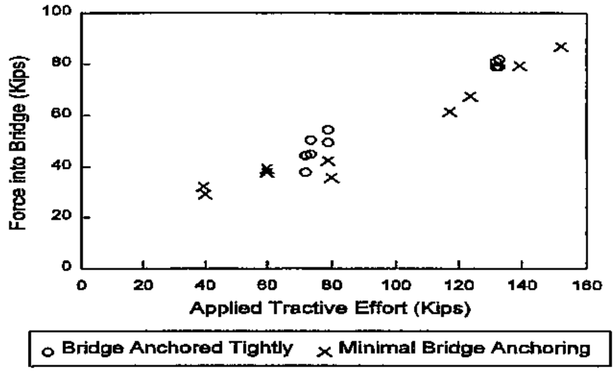

Exhibit 2. Force into Bridge with Approaches Anchored Tightly

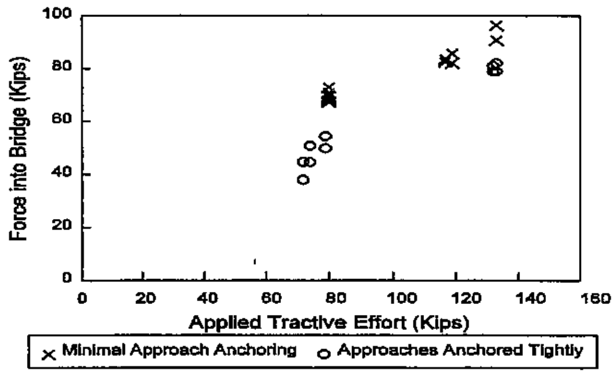

Exhibit 3. Force into Bridge with Bridge Anchored Tightly

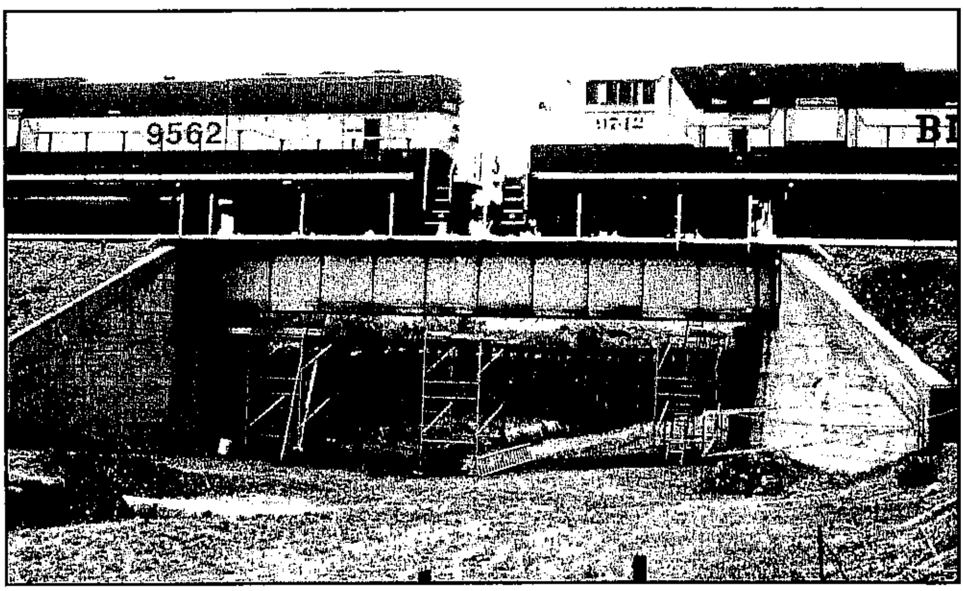

Exhibit 1. AC Locomotives Crossing Test Bridge

Exhibit 4 shows the results from the train passes when the rail on the bridge was minimally anchored. In this case, the effect of anchoring the rails on the approaches is barely discernable. Anchoring the rails on the approaches may offer a slight reduction in force reacted by the bridge.

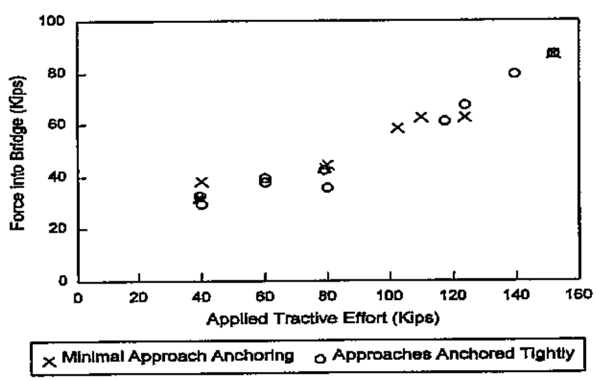

Exhibit 4. Force into Bridge with Minimal Bridge Anchoring

IMPLICATIONS

The measured longitudinal forces into the bridge are more than an order of magnitude higher than the design values currently recommended by AREA. The current AREA design loading is less than 4 kips for a 50-foot steel span, compared to measured forces of nearly 100 kips.

The maximum measured longitudinal force into the bridge is roughly 25 percent of the locomotive weight applied to the bridge, which is similar to the design guidelines used before 1968. The current AREA guidelines for timber bridges still recommend designing for 25 percent of the weight on locomotive drivers in some cases.

The test results also show that, as applied tractive effort increases, so does the longitudinal force that must be reacted by the bridge. Therefore, the higher tractive effort available with AC locomotives as compared to DC locomotives, results in higher longitudinal forces into the bridge. However, even for tractive effort levels typical of DC locomotives, the longitudinal force into the bridge is much higher than the AREA design value.

The AAR, in conjunction with researchers at the University of Illinois, will use the measurements from these tests to calibrate an analytical model to extend the results of this test to other bridges. They will also share the results with appropriate AREA technical committees.

Further testing is recommended to determine the longitudinal forces in spans of different lengths and in spans with ballasted decks, as they could vary significantly. Differences in bridge construction and anchoring details that could reduce the effects of these higher longitudinal forces should be investigated. Longitudinal forces induced by thermal effects in continuous welded rail should also be considered.

ACKNOWLEDGMENTS

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