TECHNOLOGY DIGEST

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Seismic Resistance Tests on an Open-Deck Steel Bridge

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Summary

Properly anchored rail and bridge decks can provide significant resistance to ground motion. This may be enough to eliminate the need for seismic retrofits of many railroad bridges.

Transportation Technology Center, Inc. performed tests in 2000 to assess the ability of railroad bridges to withstand earthquakes and to make decisions about retrofitting bridges to withstand longitudinal movement. The objective of these tests was to determine the resistance to longitudinal movement provided by the track structure and approaches. The tests were conducted on an out-of -service multispan open-deck bridge on an industrial lead of the Union Pacific Railroad. Test results are summarized as follows:

- **Frictional resistance of a 53-foot intermediate span:** Coefficient of friction resistance for longitudinal movement with the bearings greased and rails disconnected was 0.21.
- **Longitudinal resistance between rail and bridge deck:** Total resistance was 31 kips for a 53-foot intermediate span on tangent, and 45 kips for a 53-foot end span in a 4-degree curve with rails not anchored.
- **Longitudinal resistance between bridge deck and span:** Total resistance was 47 kips for the intermediate span, and 44 kips for the end span with rails anchored and hook bolts loose.
- **The longitudinal resistance of the whole system:** Total resistance for the intermediate span with rails attached to both ends was 62 kips with the rails box anchored at every other tie and hook bolts on every other tie tightened to specification. For the end span with rails attached only to the approach, the frictional resistance was 58 kips.
- **Longitudinal resistance provided by the approach:** The rail and/or deck moved before the approach could be pulled loose.

The results of these tests will be shared by AAR member railroads through the Bridge Research Advisory Group. Results will be used by Committee 9 — Seismic Design for Railway Structures in the development of AREMA manual provisions on design and retrofit of railway bridges for earthquake resistance.

Suggested Distribution:
- ❑ Maintenance of Way
- ❑ Bridge & Structure
- ❑ Track Maintenance
- ❑ Safety

Work performed by Transportation Technology Center, Inc.
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INTRODUCTION

In order to assess the ability of railroad bridges to withstand earthquakes, information is needed to quantify the resistance of existing bridges to horizontal ground motions. With this information, decisions can be made about the need to retrofit a bridge, and if so, what sort of retrofit might be appropriate.

The purpose of the tests on intermediate span 5, shown in Exhibit 1, was to quantify the resistance between rail and bridge deck, and the resistance between bridge deck and the span. The test was to determine how much resistance to longitudinal movement was contributed by friction, the hook bolts, and box anchoring of the ties. End span 1 shown in Exhibit 2 was used to test the resistance provided by the full system, including the approach embankment.

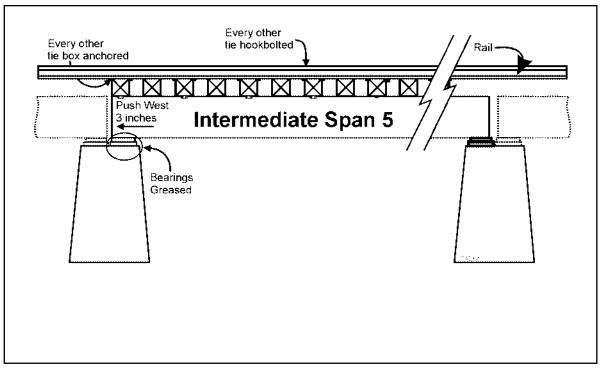

Exhibit 1. Elevation of Intermediate Span

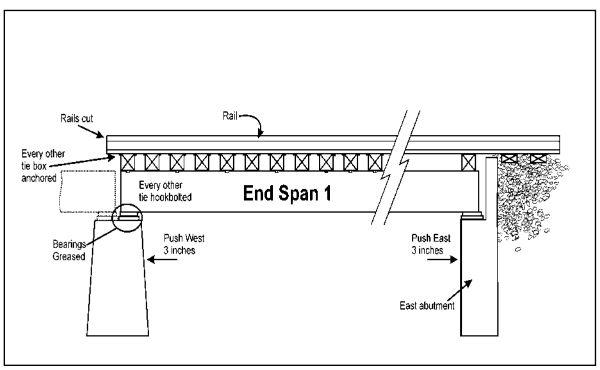

Exhibit 2. Elevation of End Span

TEST PROGRAM

Steel reaction frames were installed on the two piers under intermediate span 5 and the pier and the east abutment of end span 1. Four 50-ton jacks were used for jacking, one at each corner of the spans. The anchor bolts on both spans were cut and the bearing plates greased. The walkway timbers were cut between spans and the guardrails were removed from the bridge. Each span was subjected to a series of longitudinal pushes by hydraulic jacks.

Displacement measurements were taken at the interfaces of the rail to tie, tie to beam, and beam to pier. Strain gages were used to measure the forces in the rails. Load cells were used to measure the force needed to move the span.

Six tests were performed on intermediate span 5, and four tests were performed on end span 1. Each test consisted of a push to the west and then a push to the east. After each push, the span was inspected and any changes were documented.

LONGITUDINAL RESISTANCE TEST RESULTS

The first three tests on the intermediate span were:

- With rails disconnected.
- With the rails connected, hook bolts loose and no rail anchors.
- With rails connected, hook bolts tight, and no rail anchors.

These tests indicated that the frictional resistances for the girders were approximately the same; i.e., 26 kips. Exhibit 3 illustrates the movement of the deck and girder in reference to the rails. The ties moved with the span as can be seen by the mark on the girder next to the middle tie.

The next test had all the hook bolts loose on the intermediate span, every other tie box anchored, and all spikes driven down. Exhibit 4 shows the amount of resistance provided by the box anchoring of every other tie. The average resistance for this test was about 47 kips, which is 20 kips additional resistance compared to the base case of span friction only.

For the last test on the intermediate span, all of the hook bolts were tightened, every other tie on the span was box anchored, and all spikes were driven down. This situation created a stick-slip action in the span that yielded an average resistance of 62 kips, as Exhibit 5 shows.

The tests conducted on the end span were similar to tests on the intermediate span but with two differences in rail configuration; namely, the rails were cut between end span and the adjacent span (i.e., No. 2) and the approach rails were left connected. With the hook bolts loose and the rails not anchored, as Exhibit

6 shows, the average resistance was 44 kips. Box anchoring every other tie yielded an average resistance of 44 kips. The whole system combined, with all components tight, produced a peak resistance of 100 kips as Exhibit 7 shows and an average resistance of 62 kips. Failure to pull the east approach loose happened when the girder slid through the hook bolts. Exhibit 8 shows the movement of the girder through the hook bolts with all components of the rail to deck, and deck to beams, tight on end span.

Under all test conditions, no significant movement was noted in the track on the approach embankment. Every approach tie was box anchored for about 100 feet off the bridge. The results of the longitudinal resistance tests are summarized in Exhibit 9.

BRIDGE DESCRIPTION

The test-bridge was a former Missouri Pacific Railway structure now owned by the Union Pacific Railroad. It had been out of service for a number of years. It was 527 feet, 7 inches long, and consisted of a 34-foot deck plate girder span, a 175-foot through truss span and six 52-foot, 6-inch beam spans, all open deck. The tests were performed on intermediate span 5 and end span 1. These spans were made up of four beams with welded cover plates each, and flat plate type bearings, They weighed about 127 kips each, complete with rails and deck.

ACKNOWLEDGMENTS

The authors thank the following Union Pacific employees: Darrel Deterding, Chief Engineer-Construction & Structures; Mike Freeman, Director of Bridge Maintenance; John Sprouse, Manager of Bridge Maintenance, and Ralph Prijatel, Bridge & Building Foreman, and his crew for their assistance with the tests.

Exhibit 3. Intermediate Span –
Deck and Girder Movement

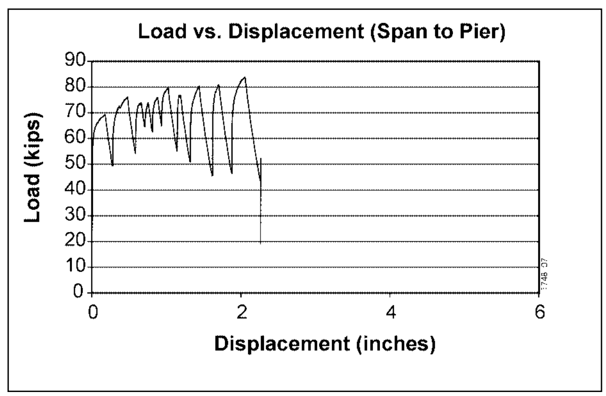

Exhibit 5. Intermediate Span – Every Other Tie
Box Anchored and Hook Bolts Tight

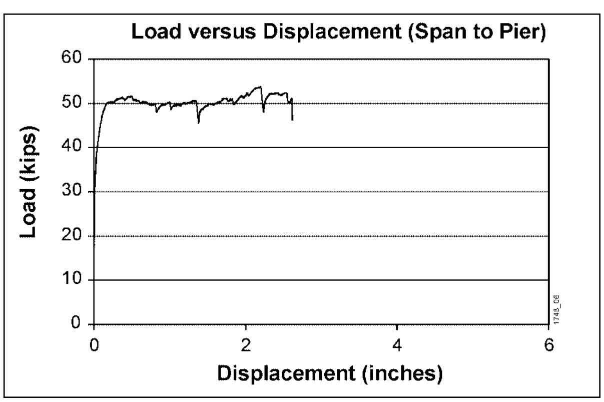

Exhibit 4. Intermediate Span – Every Other Tie
Box Anchored and Hook Bolts Loose

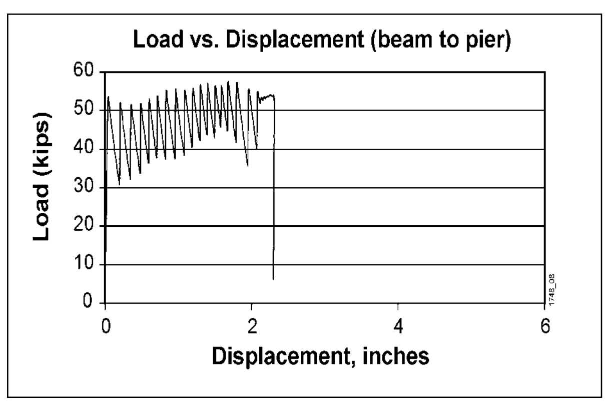

Exhibit 6. End Span – Friction between Deck,
Girder and Bearing

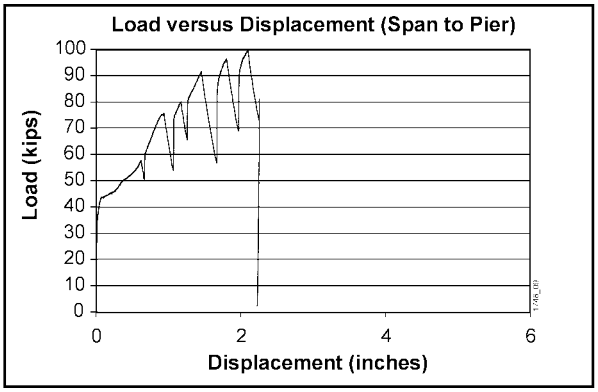

Exhibit 7. End Span – Rail Tight and Hook Bolts Tight

Exhibit 8. End Span – Hook Bolt to Top Flange

Exhibit 9.

Intermediate Span 5 — Test Results				
Test	**Loads (kips)**	**Coefficient of Friction**	**Location of Movement**	**Remarks**
Measure Bearing Friction	27	0.21	Deck, rails, and girders moved as one	Rails at both ends disconnected
Rail-to-Deck Loose Deck-to-Beams Loose	31	0.24	Between rail and ties	Rails re-attached added 3 kips resistance
Rail-to-Deck Loose Deck-to-Beams Tight	31	0.24	Between rail and ties	Tightening of hook bolts did not change the plane of movement
Rail-to-Deck Tight Deck-to-Beams Loose	47	0.37	Anchored ties stayed with rails, unanchored ties moved with girder	Rail anchors added 20 kips additional resistance
Rail-to-Deck Tight Deck-to-Beams Tight	62	0.49	Between deck and girder	Total system provided 35 kips of additional resistance
		End Span 1 – Test Results		
Test	**Loads (kips)**	**Coefficient of Friction**	**Location of Movement**	**Remarks**
Rail-to-Deck Loose Deck-to-Beams Loose	44	0.35	Between rail and ties	Rail between Span 1 and Span 2 Cut
Rail-to-Deck Loose Deck-to-Beams Tight	45	0.36	Between rail and ties	East approach attached. Hook bolts added 1 kip resistance
Rail-to-Deck Tight Deck-to-Beams Loose	44	0.35	Between deck and girder	Rail anchors added no additional resistance but changed the plane of movement
Rail-to-Deck Tight Deck-to-Beams Tight	58	0.46	Between deck and girder	Whole system provided 14 kips resistance

Note: Please contact Duane Otter at (719) 584-0594 or Shakoor Uppal at (719-584-0749) with questions or comments about this document.

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