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Very Cold Weather Testing of Thermal Effects of CWR on a Five-Span Deck Girder Bridge with Frozen Bearings

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Summary

The Transportation Technology Center, Inc. (TTCI) performed a study on a five-span steel deck plate girder railroad bridge to examine thermal effects between continuous welded rail (CWR) and the bridge. The bridge is located in northern Minnesota and experiences extreme temperature variations on a seasonal basis. During this test ambient temperature were recorded from -35 to 98 degrees F, resulting in a range of 132 degrees F. A range of rail temperatures of 161 degrees F and of girder temperatures of 120 degrees F was recorded during the test period.

Current AREMA recommendations for CWR on open-deck steel spans are based on simple models and on the assumption that nearly all span movements are realized at the bridge expansion bearings. However, test observations show otherwise.

- Locked connections can have a significant influence on expected bridge behavior. This bridge had an unusual expansion provision between the main girder and the adjacent girders. In this case, the connection was not acting as designed, resulting in noticeably different behavior than expected.
- No influence of girder movement on rail forces was noted. Measured rail forces were similar to what would be expected based on measured rail temperature. Overall, movement was reduced because of the locked seated connection between Spans 3 and 4. Movement between rail and girder in this case appears to contribute to prevention of buildup of thermal forces between rail and girder.
- Elastic rail fasteners allow limited rail longitudinal movement while continuing to provide constant longitudinal resistance (friction) without gouging deck ties. No damage to deck ties was observed during the course of testing. Elastic fasteners are used over the entire length of the bridge.

This study was conducted by TTCI as part of the Association of American Railroads' Strategic Research Initiatives Program on railroad bridges.

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INTRODUCTION

As part of the Association of American Railroads' effort to reduce the stress state of the railroad, elimination of rail joints on bridges has been shown to significantly reduce impact and extend bridge life.[1,2,3,4] In order to remove expansion joints from long open deck bridges, better understanding and prediction capabilities are needed to deal with thermal effects of continuous welded rail (CWR). Optimizing CWR anchoring on and near bridges might also reduce the incidence of broken rails and track buckling near bridges.

Previous testing has investigated the interaction between CWR and open deck steel bridges.[5,6,7,8] The objective of this testing is to quantify the thermal behavior of a long deck plate girder (DPG) bridge span subjected to extreme temperature variations, including very cold winter weather. The northern Minnesota area is well suited from that standpoint with annual average temperature ranges of 86 degrees F. Specific test objectives include:

- Characterization of thermal track/bridge interaction forces and displacements
- Characterization of longitudinal restraint between rail and bridge superstructure

Elastic rail fasteners were used over the length of this bridge. Elastic fasteners provide longitudinal restraint (through friction) but will allow relative rail-to-superstructure movement if longitudinal rail force exceeds the fastener clamping force. No damage to deck ties was observed during the course of testing.

BRIDGE DESCRIPTION

The bridge selected for this testing is the Canadian Pacific (CP) Two Rivers South Branch Bridge near Lake Bronson, Minnesota, at mile post (MP) 354.4 on the Noyes Subdivision. Traffic is about 18 MGT per year of general freight with occasional unit trains of grain, crude, and potash.

The bridge has five spans — a 106-foot DPG center main span, surrounded by two 31-foot DPG spans on each side. All spans are open deck, with riveted girders and hook bolts every second tie. The rail on the bridge is attached with PANDROL® 'e' Clip fasteners. Concrete piers support the bridge spans. Figure 1 is a schematic diagram of the bridge.

The connection between Spans 2 and 4 and the main span are seated connections (Figure 2). Observations and measurements indicate that no relative movement was taking place at the expansion end (between Spans 3 and 4).

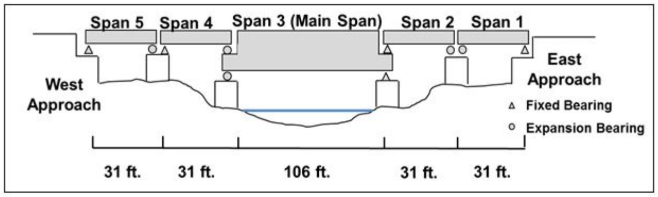

Figure 1. Bridge Schematic Diagram

Figure 2. CP Two Rivers South Branch Bridge

MEASUREMENTS

The bridge was instrumented with strain gages, temperature gages, and string potentiometers on both sides of the bridge. The following measurements were acquired:

- Rail longitudinal force
- Rail-to tie and tie-to-girder displacements
- Girder-to-pier displacements at each end of the main span
- Girder-to-girder displacement between spans both north and south girders
- Rail, girder, and ambient temperatures
- Periodic visual and/or photographic survey of deck movement, including evidence of movements of ties and hook bolts

MEASUREMENT RESULTS

Table 1 describes temperature measurements over the test period. The range of rail temperature is higher than that of girder temperature, as is typically the case. Therefore, effects from temperature changes on rail were likely higher than effects from temperature changes on the girders.

Table 1. Rail, Girder, and Air Temperature (3/12 – 5/13)

	Temperature (degrees F)		
	Maximum	Minimum	Range
Rail	128	-34	161
Girder	94	-28	122
Air	98	-35	133

The rail neutral temperature (RNT) on the subject bridge was estimated to be 85 degrees F based on comparison of observed rail movement to rail temperature when the rail was cut at the end of this experiment.

Theoretical rail force was calculated based on rail temperature, assuming that the rail is rigidly constrained at each end of the bridge. The effect of span movement was ignored for this calculation.

The north and south rails were instrumented for rail longitudinal force at six locations. Figures 3 and 4 show rail force data from a location between two 31-foot girders (Spans 1 and 2) with opposing expansion bearings on a common pier.

Figure 3 shows a time history of the measured and theoretical rail forces. Note that both daily and seasonal force variations are evident. Also, note the close correlation between the measured and theoretical rail forces.

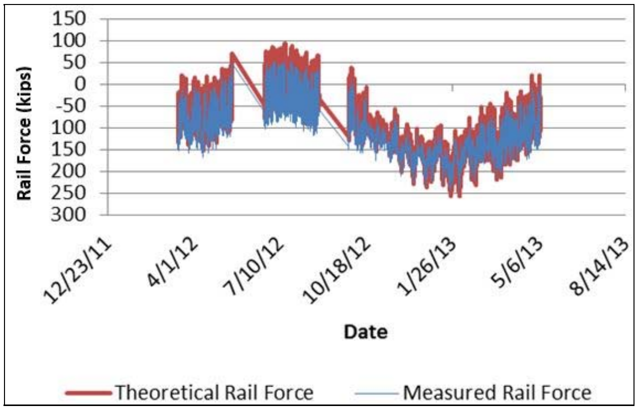

Figure 3. North Rail Force vs. Time at Connection between 31-foot Girders

Figure 4 compares theoretical and measured rail force to temperature over the entire test period. Although the values are very close, note the slight difference in the slope.

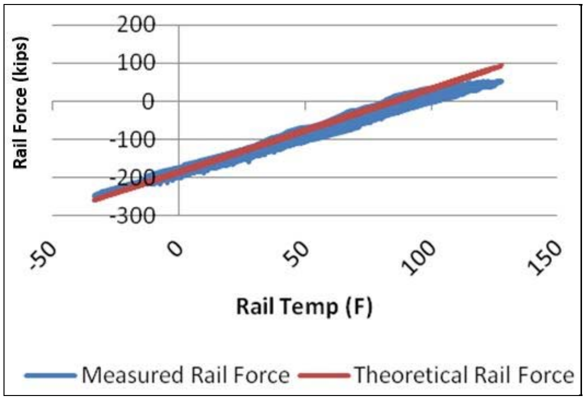

Figure 4. North Rail Force vs. Temperature at Connection between 31-foot Girders

At this location, with rising temperature and girder expansion, additional compressive forces were expected to be induced into the rail. However, the slopes in Figure 4 show less change of compressive force than was expected from the changing temperature. Potential explanations for this discrepancy include:

- The equation for theoretical rail force assumes fully fixed rail ends. In reality, some movement likely occurs.
- Changes in RNT of 30 to 50 degrees F resulting from train action and seasonal temperature variations have been observed in open track.[9]

This behavior of rail forces in response to temperature change was consistent at all other locations along the bridge. Lack of effect of girder movement on rail force indicates that the rail/tie/bridge interfaces may be allowing relative movement between the rail and the girder.

Figure 5 shows displacement between the rail and girder at the two-thirds point from the fixed bearing on the Main Span (Span 3). This displacement is assumed to be primarily between the rail and tie, because the riveted-top interface between tie and girder showed no evidence of movement. Note that the relative movement between the rail and girder shows small cyclical daily variations and a relatively larger, longer-term variation, possibly due to cumulative effects of train action. These long-term movements are likely due to rail sliding through the elastic fasteners. In spite of these movements, no damage to deck ties was observed during the course of testing. This is likely due in part to the use of elastic rail fasteners rather than rail anchors on the bridge.

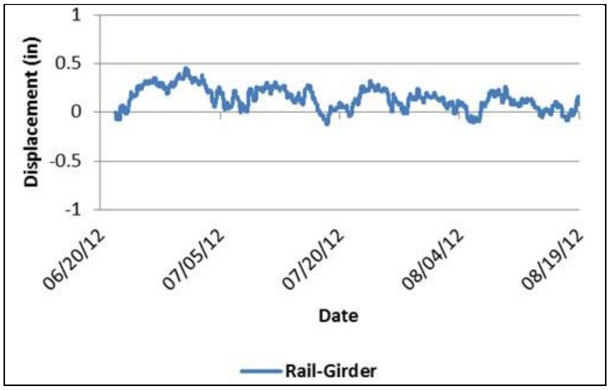

Figure 5. North Rail-Girder Displacement

Figure 6 shows the time history of theoretical and measured displacement between the main span (Span 3) and its west pier.

Provision for relative movement between Span 3 and the adjacent 31-foot span (Span 4) consists of a slotted hole where the smaller girder rests on the main span (see Figures 1 and 2). Measured movement across this connection was negligible, indicating that it was substantially locked.

Note that both daily and seasonal displacement variations are evident in Figure 6. Also note that the girder is expanding and contracting significantly less than would be predicted assuming the girder expands freely. A contributing factor may be the locked seated connection.

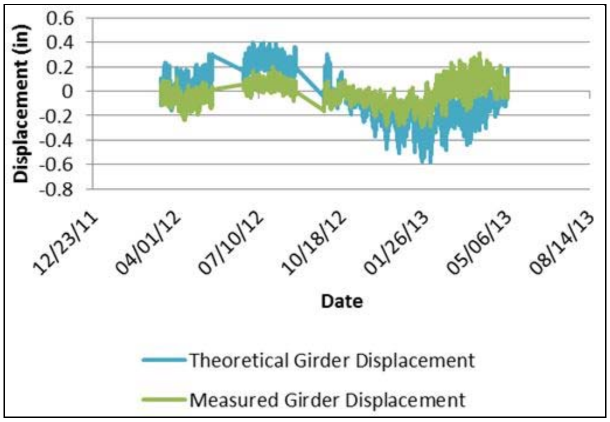

Figure 6. Main Girder to Pier Displacement vs. Time

OTHER OBSERVATIONS

In spite of measured movements between rail and girder, no damage to deck ties was observed during the course of testing. This is likely due in part to the use of elastic rail fasteners rather than rail anchors on the bridges.

Figure 7 compares simulated deflection of a rail and girder for a simplified single 106-foot span surrounded by ballasted track. The idealized simulation assumes a fully fixed bearing on the left and a fully functioning expansion bearing on the right end. The maximum girder temperature range considered was 120 degrees F, approximately the range observed during this test.

Note that at the expansion end, the girder deflects about 0.5 inch more than the rail. This indicates that there can be significant differential displacement between rail and girder. Elastic fasteners can potentially accommodate the movement by allowing the rail to slide while retaining longitudinal rail resistance (through friction) and without damaging the ties.

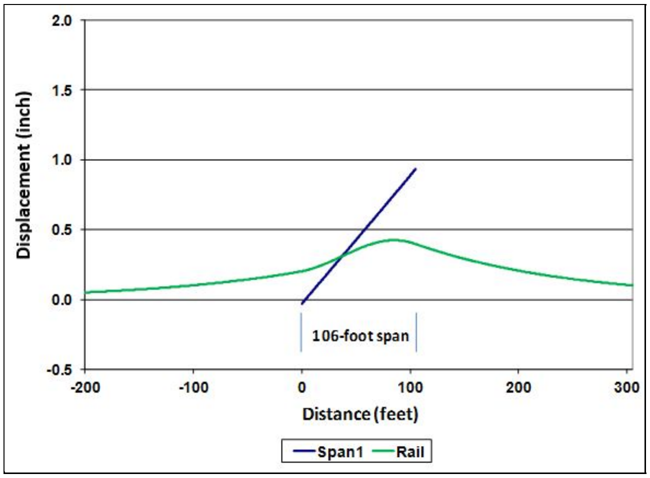

Figure 7. Simulated Deflection of a Rail and Girder for Simple 106-foot Span

CONCLUSIONS

TTCI's testing and analysis of the CP Two Rivers South Branch Bridge provided the following conclusions:

- Locked connections can have a significant influence on expected bridge behavior. This bridge had an unusual expansion provision between the main girder and the adjacent girders. In this case, the connection was not acting as designed, resulting in noticeably different behavior than expected.
- No influence of girder movement on rail forces was noted. Measured rail forces were similar to what would be expected based on measured rail temperature.
    - Overall movement was reduced because of the locked seated connection between Spans 3 and 4.
    - Movement between rail and girder in this case appears to contribute to prevention of buildup of thermal forces between rail and girder.
- If longitudinal rail force exceeds elastic fastener force, elastic rail fasteners allow limited rail longitudinal movement while continuing to provide constant longitudinal resistance (through friction) without gouging deck ties.

ACKNOWLEDGEMENTS

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