TECHNOLOGY DIGEST
TD-06-020
©August 2006
TIMELY TECHNOLOGY TRANSFER

The work described in this document was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Reduction of CWR Expansion Joints on a Long Open Deck Bridge

David Read, Duane Otter, and Brian Doe

Summary

As part of an effort to reduce the stress state on railroad bridges, reducing the number of rail joints on a bridge can be particularly effective. Both vertical and lateral impact forces can be minimized.[1,2] Reducing the number of continuous welded rail (CWR) expansion joints from four to two joints on a long open deck bridge appears to be successful, based on a recent test by the Transportation Technology Center, Inc. on a CN bridge.

Results of longitudinal rail force and displacement measurements taken on the unanchored CWR of a 1,650-foot long open deck steel bridge indicated that:

- Relocating expansion joints so that the length of unanchored rail at the joint increased from 980 to 1,450 feet, showed no negative effects in terms of rail longitudinal forces or displacement. The relocation allowed for a reduction in the number of joints on the bridge from four joints to two.
- CWR behavior appeared to be adequately controlled with the two remaining expansion joints, such that risks of track buckling and rail breaks are not increased.
- Longitudinal rail forces were primarily due to traction forces rather than temperature changes. Force changes as high as about 80,000 pound peak-to-peak independent of temperature change were measured with several of these reversals occurring in a 24-hour period.
- Longitudinal displacement of the unanchored rail corresponded to changes in the rail temperature; however, displacements 2 to 3 inches larger than possible from expansion alone, indicated significant traction effects.

Reducing the number of rail expansion joints on this bridge should provide several benefits:

- 50 percent reduction in cost of joints
- 50 percent reduction in maintenance of joints
- Reduction in track window time for maintenance
- Reduced impact forces into the bridge superstructure
- Extended bridge life and reduced bridge superstructure maintenance
- Smoother ride for freight and passengers

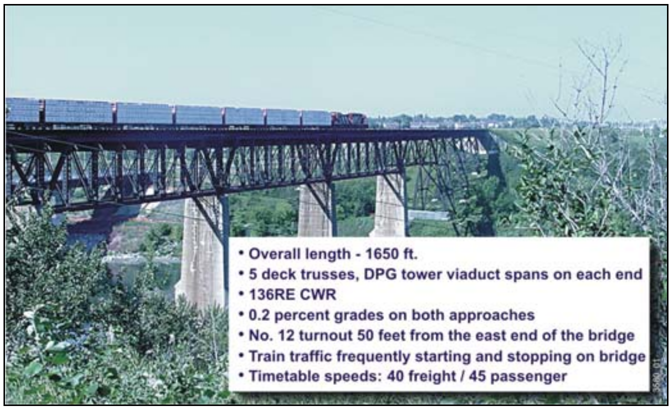
This work was performed as part of the Association of American Railroads' (AAR) Strategic Research Program on reducing the stress state of railroad bridges.

Please contact **Duane Otter (719) 584-0594** with questions or concerns regarding this *Technology Digest.* E-mail: duane_otter@ttci.aar.com.

Introduction

A question bridge engineers face is how to deal with CWR issues on a bridge deck. For long open deck bridges, expansion joints have typically been used to minimize risks of rail break, track buckling, and transfer of thermal forces into the bridge superstructure. But these joints are costly, and maintenance intensive, and can induce undesirable impact forces into the bridge. Reducing the number of these joints has significant potential benefits.

Figure 1 shows a bridge near Edmonton, Alberta, that was chosen by TTCI and CN to measure the longitudinal force and displacement behavior of unanchored CWR on a long open deck bridge. The test was performed in two Phases. In Phase 1, back-to-back expansion joints were located on each rail near the center of the bridge. In Phase 2, one joint per rail was moved to the east end of the bridge and the other joint was eliminated. In the revised layout, the single expansion joint was exposed to 1,435 feet of unrestrained rail on the west side deck and 200 feet of rail fastened with Pandrol E clips on the east side deck. The expansion joint re-configuration provided for a Phase 1 and 2 before and after comparison of thermal forces and displacements.



- Overall length - 1650 ft.
- 5 deck trusses, DPG tower viaduct spans on each end
- 136RE CWR
- 0.2 percent grades on both approaches
- No. 12 turnout 50 feet from the east end of the bridge
- Train traffic frequently starting and stopping on bridge
- Timetable speeds: 40 freight / 45 passenger

Figure 1. Open Deck Test Bridge

Welded rail that is anchored to restrain thermal expansion generates tensile or compressive thermal forces when the rail temperature differs from the rail's neutral temperature. These forces can exceed 200,000 pounds per rail and they can affect the bridge structure if released. The instantaneous release of the existing longitudinal force when a rail is cut or broken while in tension (rail temperature below the neutral temperature) has the highest potential for transmitting a significant CWR thermal load into the structure. Unrestrained rails generate little if any thermal force, but expansion joints are required to accommodate the longitudinal movement of the rail. Should the rail be fully restrained, as with ballasted track, or unrestrained and allowed to move with temperature changes? The data collected during this project will be used to develop a model to predict CWR thermal force and longitudinal movement and determine the most effective CWR anchoring practice for specific bridge types and configurations.

Description of Test

The 1,650 foot long open deck steel bridge was selected because: (1) the 136 RE CWR was unrestrained longitudinally with back-to-back manganese casting expansion joints located on each rail near the center of the bridge, and (2) CN was planning to move one expansion joint per rail to the east end of the bridge and eliminate the other joint in order to reduce maintenance. Figure 2 shows the Phase 1 and 2 expansion joint layouts. In the revised layout, the single expansion joint was exposed to 1,435 feet of unrestrained rail on the west side deck and 200 feet of rail fastened with Pandrol E clips on the east side deck. The expansion joint re-configuration provided the opportunity for a Phase 1 and 2 before and after comparison of thermal forces and displacements.

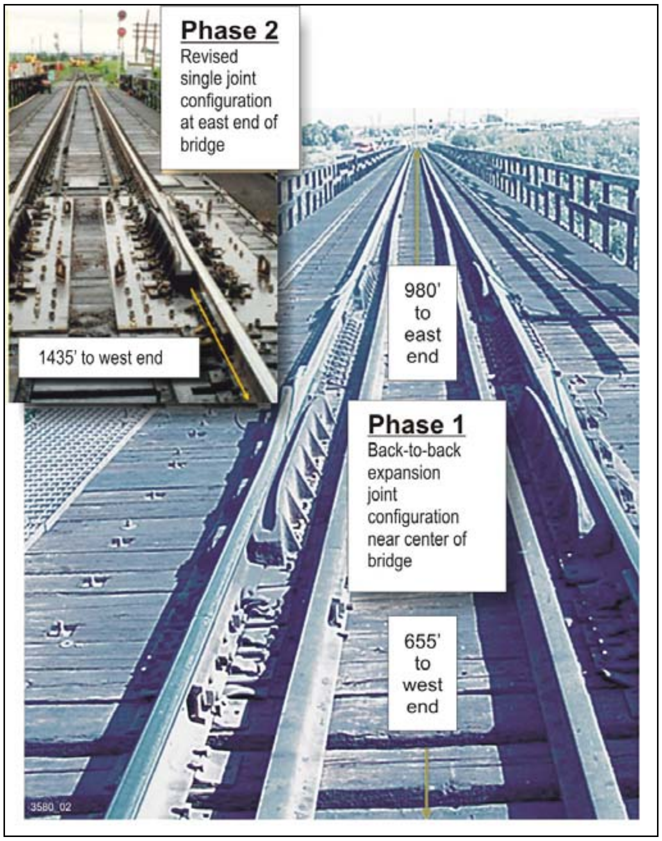


Figure 2. Rail Expansion Joint Layout during Test Phases 1 and 2

Measurements were similar in both test phases and included:

- Longitudinal rail force from strain gages (Note that the forces measured were not absolute as the output of the strain gage circuits were not corrected to a stress-free rail condition, although near expansion joints, rail is essentially stress-free)
- Longitudinal rail movement relative to the ties
- Longitudinal tie movement relative to the top of the span
- Span-to-span displacement
- Rail and span temperatures

In October 2003, Phase 1 data was collected at 15-minute intervals over 48 hours and Phase 2 data, at the same frequency, over 29 days in September through October 2004.

Test Results

As expected, the expansion joints near the center of the bridge (Phase 1) were very effective at minimizing thermal forces in the rail. The top plot in Figure 3 shows the longitudinal rail forces measured 800 feet from the expansion joint along with the measured rail temperature. The theoretical change in thermal force of a restrained rail is also included in the plot to give a thermal force perspective. Comparing the measured and theoretical forces clearly indicates minimal thermal force affects. The force fluctuations in Figure 3, therefore, appear to be produced by train traction forces rather than temperature.

The lower plot in Figure 3 compares the measured longitudinal rail displacement at the east expansion joint that was exposed to 980 feet of unanchored rail with the theoretical rail expansion for the same length of rail over the same time period as the force plot. The measured displacement of the unanchored rail generally follows the theoretical expansion response but also has fluctuations not related to changes in temperature and that coincide with the train-induced force fluctuations.

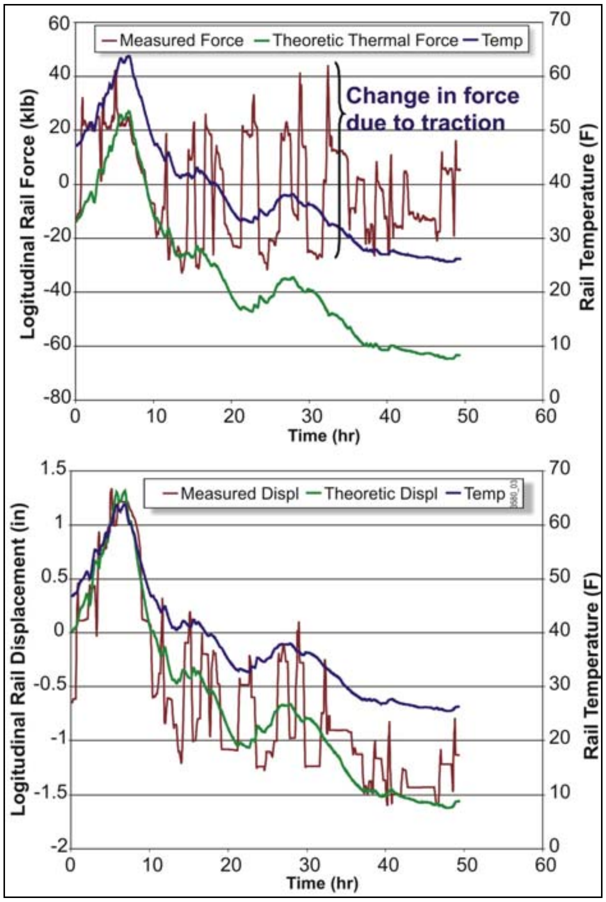


Figure 3. Phase 1 Longitudinal Rail Force, Displacement, and Temperature Data

Other data collected in Phase 1 included longitudinal tie displacement relative to the span and span-to-span displacement. The tie/span displacements were less than 0.5 inch indicating that the ties were generally moving with the span and the rail was moving freely through the tie plates.

Figure 4 shows span-to-span displacement measured between the top chords of the 225 foot spans. Both spans have expansion bearings on the pier below this measurement location. Note that the measured displacement closely follows the theoretical displacement for the recorded change in temperature. This indicates the span is moving freely with temperature at the top of the span where the measurement was taken. It is not being restrained at the measurement point by rail forces or frozen bearings. Expansion was not measured at the bottom of the span, therefore, the ability of the bearings to accommodate expansion/contraction at the bottom of the span is not known.

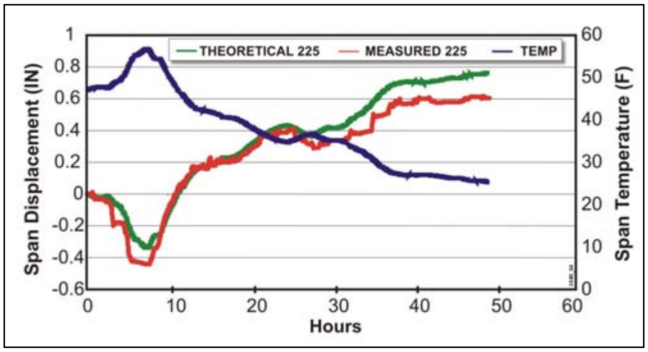


Figure 4. Phase 1 Span-to-Span Displacement and Temperature Data

Figure 5 shows rail longitudinal forces at various distances from the expansion joints. Note that near the joint, the force is nearly zero, as would be expected. At locations farther from the joint, the average force remains near zero, but the fluctuations due to train traffic are greater as the distance from the joint increases. It is likely that the increased frictional resistance between rail and ties, due to the greater length of rail, allows for the build-up of greater forces away from the joint.

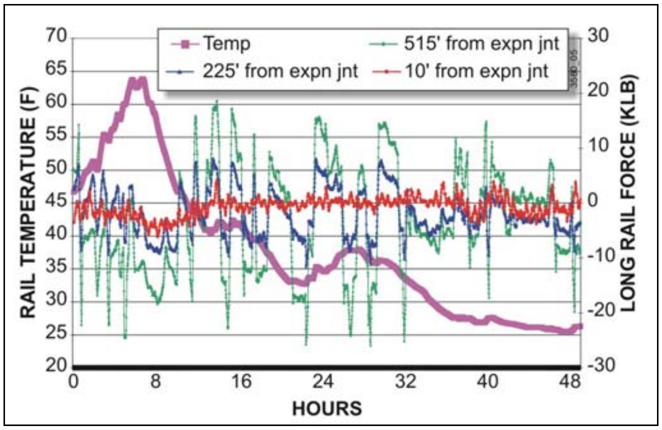


Figure 5. Phase 1 Longitudinal Rail Forces at Various Distances from Expansion Joint

Measurements taken following relocation of the expansion joints during Phase 2 of the project yielded similar results in terms of CWR behavior as those from Phase 1. Figure 6 shows the longitudinal force and displacement data recorded in Phase 2. Although the length of unrestrained rail is longer than in Phase 1 (1,435 versus 980 feet), the force behavior is the same with the longitudinal forces being generated primarily from train rather than thermal input. The displacement data in Figure 6 is also similar to that noted in Phase 1.

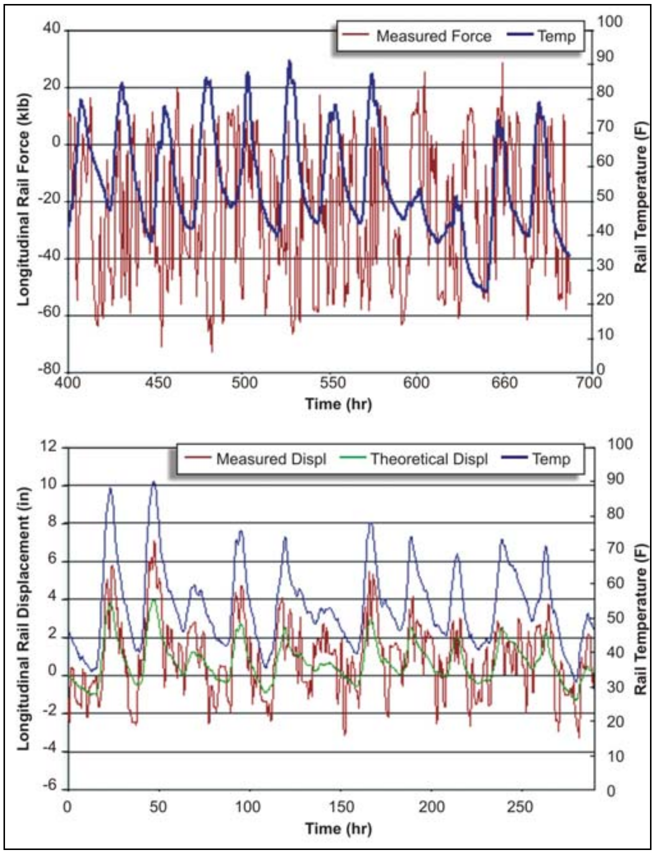


Figure 6. Phase 2 Longitudinal Rail Force, Displacement, and Temperature Data

As noted in Phase 1, differential movement of the ties relative to the spans was again, less than 0.5 inch. Span-to-span displacement measurements again showed the tops of the spans to be moving freely with temperature at the sliding bearing ends of the spans.

Conclusions

- The re-configuration of expansion joints was successful as there was no adverse effect in terms of longitudinal force levels by eliminating two of the four joints on the bridge.
- Longitudinal forces measured on the unanchored rail across the bridge deck were attributed primarily to traction forces rather than temperature changes. The force levels tended to increase with distance from the expansion joints as was expected. Force changes as high as about 80,000 pounds (about 6 ksi rail stress) peak-to-peak were measured 1,155 feet from the expansion joint with several of these reversals occurring in a 24-hour period.
- Longitudinal displacement of the unanchored rail at the expansion joints followed the rail temperature; however, the magnitude of displacements measured were larger than possible from temperature change alone. The higher frequency rail displacements that exceeded the possible thermal expansion were generated by the train traction forces. The highest traction induced displacements were measured at the expansion joints corresponding to the lowest force changes. Displacements measured at the end of the rail furthest from the expansion joints where the train induced longitudinal forces were higher tended to be less than those at the joints.
- The lack of differential longitudinal movement of the ties relative to the spans was not expected. Data from Phase 1 showed the movement between two spans to be about 0.2 inch more than movement of the ties relative to the spans indicating the ties were moving with the spans. There was visual evidence, however, at other locations that showed the spans were moving independent of the ties.
- It is recommended that a similar test be performed on a long open deck bridge on which the CWR is fully anchored for further comparisons.

Acknowledgements

TTCI staff are grateful for the support and cooperation on CN during this test. In particular, Jose Cavaco and Lyle Pederson provided essential assistance throughout.

References

1. Doe, Brian, Charity Sasaoka, David Davis, and Duane Otter. April 2005. “The Evaluation of Amtrak Thick Web Miter Rail Movable Bridge Joint under HAL Traffic,” *Technology Digest*, TD05-011, Transportation Technology Center, Inc., Association of American Railroads, Pueblo, Colorado.
2. Akhtar, Muhammad, Duane Otter, and Brian Doe. April 2005, “Preliminary Impact Load Assessment of Ballast Deck Prestressed Concrete Bridges,” *Technology Digest*, TD05-013. Transportation Technology Center, Inc., Association of American Railroads, Pueblo, Colorado.