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Evaluation of a Thick-Web Miter Rail Joint and Signal System Interface under HAL Traffic

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Summary

The Transportation Technology Center, Inc. evaluated the effects of Heavy Axle Load (HAL) traffic on a long-point, thick-web miter rail system designed by Amtrak and manufactured by Cleveland Track Materials. The associated signal system components were also tested. The Association of American Railroads' Strategic Research Initiatives Program sponsored the trial. TTCI performed the test on the steel bridge at the Facility for Accelerated Service Testing (FAST), Pueblo, Colorado.

The bridge joints were installed in February 2004 and were removed September 2005. They accumulated approximately 201 million gross tons (MGT) of 315,000-pound HAL traffic. The following observations were made:

- These joints lasted three to four times longer than the miter rail joints previously tested at FAST. Very little maintenance was required until the joints were near the end of their service life.
- The joints are safe for 39-kip wheel load operation.
- Replacement of a set of points would enable these joints to last significantly longer, as the points were the only component to show significant degradation.
- Dynamic vertical and lateral wheel forces increased 30 to 70 percent over the life of the joints.
- Three sets of steel proximity switch brackets designed in conjunction with the Amtrak signal department failed within 5 MGT.
- TTCI designed and fabricated Delrin plastic brackets that accumulated about 41 MGT with no problems. These targets were still performing well until the removal of the bridge joints.
- Thermal expansion of the rail was a problem for the signal system, causing the target to move enough to indicate a discontinuity. Modifications to the target brackets solved this problem.
- The proximity sensors performed well from their installation until their removal, accumulating 161 MGT.

Implementation of improved-design miter rail joints on moveable bridges could result in a significant decrease in maintenance and replacements. Likewise, some inexpensive modifications to the associated signal system hardware could lead to a significant reduction in moveable bridge signal problems and resulting train delays.

This test was sponsored by the AAR, the U.S. Department of Transportation, and the Federal Railroad Administration as part of the AAR's Strategic Research Initiative program and the FAST HAL program.

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Introduction

Bridge miter rail joints are known as bridge joints, slip joints, moveable bridge joints, miter rails, lift rails, and miter joints, but all serve the same purpose. They are designed for moveable bridges where special rail joints are required at each end of a moveable span. Dynamic loading on bridge joints often causes excessive rail batter requiring frequent maintenance. Ride quality may also be affected.

Transportation Technology Center, Inc. (TTCI) recently completed testing a long-point, thick-web rail joint system. TTCI performed the test in Section 5 of the Facility for Accelerated Service Testing (FAST). Section 5 contains an open deck bridge with two steel deck plate girder spans.

This particular type of bridge joint is designed for a swing bridge application. This design is also adaptable to lift or bascule bridges. Amtrak presently holds a patent on this design. It is presently used on selected Amtrak bridges. The swing bridge type long-point, thick-web miter rail system with its lift rails is the longest version of this system. It consists of five sets of bedplates covering a distance of approximately 45 feet.

The approach and lift rails are made of 136 RE thick web rail material and the rail ends are flash butt welded to standard 136 RE rail. The bed plates are made of fabricated steel. Many of the components, including the long built-in guardrail system, are made of special hardened steel. The miter points are long and, by design, make the transition from approach rail to lift rail virtually seamless. The thick-web rail allows for additional web material at this critical long point transition area. In particular, the thick web provides much better support for the rail head at the points. Figure 1 shows the bridge joint. The signal system components, including proximity sensors and targets can also be seen near the points in Figure 1.

Figure 1: Amtrak Long-Point, Thick-Web Bridge Joints Installed on the Steel Bridge at FAST

Test and Results

The Amtrak thick-web rail bridge joints were tested on the High Tonnage Loop (HTL) at FAST. The FAST train typically has 70 to 80 cars with 39-ton axle loads. HAL traffic runs in both directions with the number of cycles and tonnage documented. The train normally operates at 40 mph. There are typically no flat wheels in the train consist. The miter joints accumulated approximately 4 to 5 MGT of HAL traffic per week.

The Amtrak bridge joints were installed in Section 5 on an open deck test bridge with two steel deck plate girders spans. The longest span has a length of 65 feet and a depth of 69.25 inches. The other span has a length of 55 feet 6 inches and a depth of 63 inches. The bridge lies in the middle of a 210-foot long tangent of Section 5. There are spirals and curves at each end of Section 5.

The joints were installed between spans on the bridge. The fixed side of the joints was on the longer bridge span and the lift side of the joints was on the shorter bridge span. The lifting rods are attached to the rails and are secured to the bottom of the spans with two channel sections, which have the rods going through them. There are two nuts holding the springs against the channels compressing the springs to maintain the specified tension.[1]

Other than the discontinuity at the miter joint, the rail surface was continuous and smooth over the entire bridge.

Miter Rail Joint Performance

The joints accumulated 201 MGT and generally performed well. Very little maintenance was required until the joints were near the end of theirservice life. The primary maintenance required was to grind the rail at the points. Towards the end of the joints service life, maintenance grinding was done about every 2 MGT on one of the fixed points. This point may have had slightly softer steel as it required the most attention. The fixed end guardrail plates had four broken bolts replaced. The broken bolts appeared just before removal of the system.

Two weld build-up repairs were done to try to extend the life of the points. The first weld build up was performed at 195 MGT and lasted for approximately 6 MGT. The second build up of the fixed and the moveable points lasted for 12 train passes. A vertical crack of 2.5 inches developed. This and the degradation of the other two points led to the removal of the joint. If 4 or 5 feet of the points could have been easily replaced, the joints would still be in track. Most of the maintenance was on one point, which was one of the two fixed end points.

The cracks in the bridge girder and bracing that developed with the previous bridge joints started to become active towards the end of the service life of the Amtrak miter joints. The crack activity most likely increased as the joints degraded due to increased vertical and lateral dynamic wheel forces.

There was no hook bolt maintenance needed at the bridge joint location during the time the miter joints were installed. The hook bolts holding the timber deck in place under the bridge joints are still performing well. As with the previous bridge joint, the hook bolts were rotating and breaking off. There are hook bolts in each deck timber under the points with hook lock plates.

Signal System Component Testing

In conjunction with the bridge joint test, TTCI also tested signal system components that are typically used on moveable bridges. Reports from revenue service indicate the malfunctioning of these systems is a frequent cause of train delays.

Proximity sensors and their targets were installed on the points and were monitored for their performance. The initial targets were steel and were donated by Amtrak. They were welded onto the points, following Amtrak's standard installation procedure. The initial design failed in one day due to inadequate allowance for temperature-induced movement. Two sets of modified targets were installed but each failed within 5 MGT of traffic. These are shown in Figures 2 and 3. Failure mode each time was fatigue leading to fracture. The welds on the target brackets did not fail. The length and weight of the brackets combined with the severe vertical force environment contributed to the fractures, which occurred about an inch away from the welds and the points.

Figure 2: Steel Target and Proximity Sensor, Welded to Miter Joint

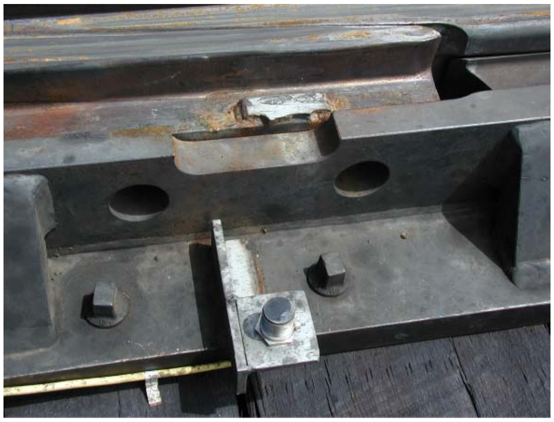

Figure 3: Broken Steel Target and Proximity Sensor, Welded to Miter Joint

After the rapid failures of the steel targets, TTCI staff designed and fabricated Delrin plastic targets with a thin sheet metal plate held in place with four screws. These targets were bolted to the points. The mounting for the proximity sensor was also changed to allow a shorter target arm, which was also bolted rather than welded. The proximity switch brackets were moved from the bottom plate to the vertical wall of the fixed end guide plate and bolted instead of welded. Compared to the steel targets, the Delrin plastic targets (shown in Figure 4) were shorter and much lighter in weight. These targets were still performing well until the removal of the bridge joints. The targets accumulated about 41 MGT with no failures.

Figure 4: New Delrin Plastic Target and Proximity Switch Bracket Bolted Instead of Welded

Once the target bracket problem was solved, a second problem was found. Rail longitudinal movement, due to the expansion and contraction of the points and train traffic, pulled the target completely off of the proximity sensor. Lengthening the base of the plastic Delrin target and slotting it to slide back to the proximity switch solved this problem. By using slots, as shown in Figure 5, adjustments can be made quickly if necessary due to a change of season or rail changes nearby.

Figure 5: Slotted Target with Adjustment for Rail Longitudinal Movement

Proximity sensors have frequently been blamed for signal system problems associated with moveable bridges. However, during this test at FAST, the proximity sensors lasted for 161 MGT with no failures. It is likely that bracket failures and rail longitudinal movement problems are frequently reported incorrectly as proximity sensor failures.

Dynamic Wheel Force Environment

Quantifying the force environment provides valuable information for understanding the performance of both the joints and the signal system components.

When new, the Amtrak joints had lower vertical dynamic loads than typical mechanical rail joints. Figure 6 shows dynamic vertical wheel loads from instrumented wheel set (IWS) data for the Amtrak joints. This data was taken when the bridge joints were fairly new and again when the joints were approaching the end of its service life at FAST. The Amtrak joints had average maximum vertical dynamic loads, approximately 1.1 times the static wheel load when new. In comparison, the data from the worn bridge joints had increased to 1.44 times the static wheel load at 40 mph. Even in the worn state, the Amtrak joints had lower vertical loads than the previous bridge joints tested, as well as other special trackwork components. The previously tested joints had dynamic vertical wheel loads averaging about 1.5 times the static wheel load.

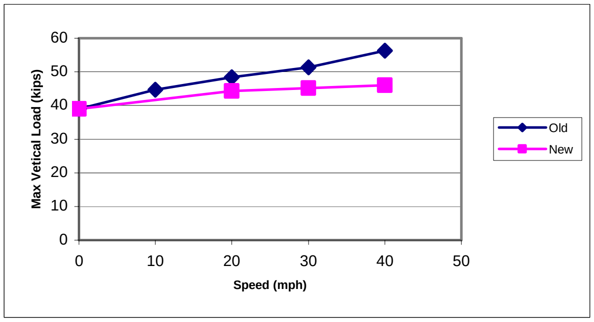

Figure 6: Average Maximum Vertical Dynamic Wheel Loads

The Amtrak joints had slightly higher lateral dynamic loads of about 1 to 2 kips more than a typical mechanical joints. Figure 7 shows average maximum lateral dynamic loads for Amtrak bridge joints in the new and worn state.

The lateral loads did not seem to increase with speed but stayed steady at about 7 kips in the new state. In the worn state at 40 mph the loads increased to 1.7 times more than the new state.

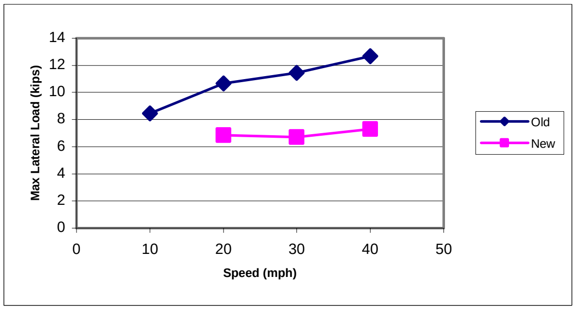

Figure 7: Average Maximum Lateral Dynamic Wheel Loads

Conclusion

The Amtrak long-point, thick-web bridge joints performed well under the 39-kip wheel loads. Little maintenance was done to this system until about 174 MGT. The increased maintenance was primarily grinding on one of the fixed rail points. Towards the end of its service life, the maintenance grinding of just the points increased until the joints accumulated 201 MGT and was taken out of track. If there was a way to replace just a few feet of the points easily, the system might still be in service.

Two weld repairs were performed in order to extend the life of the joints. The first weld build-up of the points lasted for 6 MGT. The second weld build-up of the same point lasted for 12 train passes. There was a 2.5 inch vertical crack in the area of the build-up.

The Delrin plastic signal system targets were performing well until the removal of the bridge joints. The proximity sensors continued to work from the day they were installed until removal of the joints. They had 161 MGT of traffic at the time of removal. Rail longitudinal movement due to thermal effect caused an apparent problem with the sensors. This was resolved by adjusting the target location. No proximity sensors were found to be faulty.

During the life of the joints, the maximum dynamic vertical wheel loads increased from 1.1 times to 1.44 times static wheel load at 40 mph. The maximum lateral wheel forces increased from 7.3 kips to 12.7 kips or 1.7 times more.

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