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Evaluation of a Movable Bridge Rail Joint on the Steel Bridge at FAST

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Summary

Transportation Technology Center, Inc. recently completed testing an improved-design easer rail movable bridge rail joint at the Facility for Accelerated Service Testing (FAST) to determine its performance under heavy axle load (HAL) traffic. The joint was installed over the center pier on the open deck steel bridge at FAST. Significant results include:

- The joint survived 106 MGT in HAL service before being removed because of continued cracking of base plates and rail surface deterioration resulting in high dynamic forces.
- Maximum dynamic vertical wheel forces up to 72,000 pounds were measured using instrumented wheelsets. This is a dynamic impact of 83 percent above the static wheel load.
- The joint lasted about twice as long as two previous movable bridge rail joints tested at FAST, but only about half as long as a premium high-speed design joint.
- High impact forces from the bridge joint resulted in increased cracking in the bridge span and increased maintenance demand for deck fasteners, walkways, and handrails near the joint.
- A longer transition ramp in moving from the fixed side to the movable side resulted in lower impacts in that direction when the joint was new.

This test was conducted as part of the Association of American Railroads' Strategic Research Initiatives Program. It is hoped that these results will lead to further improvements in movable bridge rail joints including longer life and reduced dynamic impact forces. Such improvements will result in better railway network reliability, reduced train delays, reduced bridge maintenance, and longer bridge life.

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INTRODUCTION

Movable bridges are often an impediment to railroad network capacity, not only because of delays due to openings for marine traffic, but also because of speed limitations and issues related to the bridge itself.[1] The rail joints at the ends of a movable span are often cause for speed restrictions, as well as a source of high dynamic impact forces into the bridge structure. In an effort to promote improved designs with longer lives and reduced impact forces, Transportation Technology Center, Inc. (TTCI) has evaluated several movable bridge rail joints.[2] This bridge rail joint described herein is an improved design of a style that was tested previously.

Because of their small numbers in service (estimated at less than 1,000), little effort has been given to improve the performance of bridge rail joints. While railways, in the last 25 years, have increased the average service life of mainline fixed point frogs by 100 percent (from 250 MGT to over 500 MGT), the average service life of bridge joints has not improved as significantly.

The effect of wheel load is quite substantial for both components. The average service life of frogs at FAST is 400 MGT under 315,000-pound gross rail load cars. The average service life of bridge joints at FAST is about 70 MGT. One might suggest the bridge joint design issue is easier than that of a turnout frog because there is no flangeway gap to cross in a bridge joint. However, there are unique problems to overcome. These include:

- A high stiffness, low damping foundation.
- Potential for differential settlement across separate bridge spans.
- Longitudinal movement of one rail versus the other rail in a joint.

Design and Installation

Progress Rail Services (PRS) provided an improved version of an easer rail bridge joint for testing. Figure 1 shows the rail joint detail for a single running rail, with wheel tread path indicated where the paint has worn off. Note how the wheel tread transfers from the running rail to the easer rail to carry the wheel over the gap in the running rail. The gap allows for thermal expansion and contraction of the rail and bridge spans, as well as other tolerances needed for a movable bridge span.

Compared to the previously tested rider-style joint, this joint features an easer rail made from a crane rail section. The easer rail is much longer than the rider block used in the previous design and allows for a more gradual transition zone, particularly on the fixed span side. The crane rail is also an easily replaceable section.

The joint was installed over the center pier of the open deck steel bridge at FAST. As with previously tested joints, the 65-foot span was considered the fixed span, and the 55.5-foot span was considered the movable span. Note that a 55.5-foot vintage riveted girder span has replaced the 55.5-foot welded girder span at this location since the previous joint tests.

The joint was installed on a solid mat of timber ties near the end of each span. The base plates were attached with bolts through the ties. On the bottoms of the ties, 4-inch square steel plate washers and double nuts with thread-locking adhesive were used to secure the through bolts. The only exception to through bolts was the use of screw spikes into the ties on the outside of the base plates for the 65-foot span, where the top flange of the girder would interfere with through bolts. Between the base plates and the timber ties, a manufacturer supplied pad was installed. The stiffness of the 3/8-inch thick pads was measured to be a durometer D reading of 72 to 75.

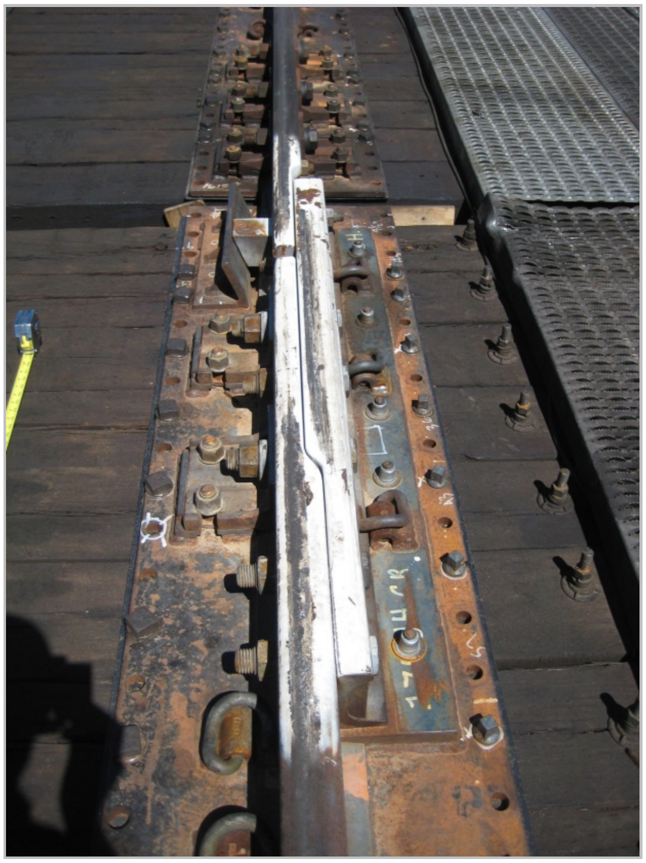

Figure 1. Rail Joint Detail for One Running Rail

Rail Profiles and Hardness

The performance of the running surfaces in the joint was monitored using cross section profiles and surface hardness measurements. From this data, the height loss rates of the joints and the work hardening rates of the rails were determined. This design features a much longer transition from the running rail to the easer rail on the fixed end of the joint. This longer transition should allow the joint to accommodate a wider range of worn wheel shapes with minimal dynamic loading. This transition is similar to those used for turnout frogs. The transition between the easer rail and the tread rail on the movable end is more problematic. The ramps must be short, so the movable span is free to move away from the fixed span. This transition also must perform successfully under the full range of temperatures the bridge experiences. Most joints are built to allow 4-6 inches of rail movement. Thus, the transition must accommodate this range of motion and still provide smooth transitions for all wheel profiles. This is an extremely difficult design problem. The PRS design, with sloped rails and a convex easer rail, is effective at supporting wheels across the rail end gap. However, it generates relatively high dynamic loading with the elevation changes most wheels see in going across the rail gap.

Wear (reported as vertical height loss) of the joint running surfaces were measured over the service life of the joints. Figure 2 shows the average height loss of the two joints (left and right rail) over 102 MGT.

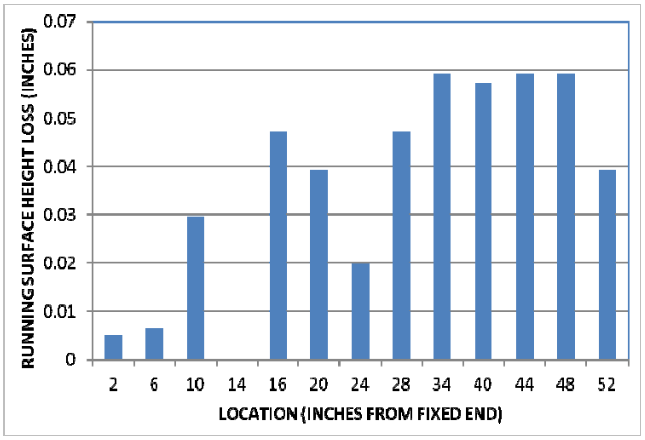

Figure 2. Running Surface Vertical Height Loss versus Location (at 102 MGT)

The height loss is greatest in the transition zone between the easer rail and the movable span running rail. The height loss is greatest over about a 24 inch length. This is the zone of wheel transfer, which is influenced by the temperature and location of the movable span rail. The same conclusion is confirmed from the running surface hardness measurements; the wheel transfer zone shows the most surface hardening.

Some refinement of the running surface profiles of the joint can be done to improve wheel-rail contact conditions. This should lower initial deformation rates and reduce dynamic loading. For example, the easer rail is made with a flat running surface and a relatively small radius "gage" corner. A sloped running surface, inclined at 1:20 to the gage side would be more conformal to the field side of the wheel tread that will contact it.

Maintenance Demand

Rail surface grinding was first performed after about 62 MGT of HAL traffic. Grinding was performed again after 30 additional MGT (92 MGT total). The flow maintenance grinding demand is less than one would expect for a manganese casting frog, but more than expected for a switch point. This is reflective of the dynamic loading the joint is experiencing.

The first sign of deterioration noted in this joint was cracking of a weld between the riser plate and the base plate on the fixed span, near the location where the rail tips from the movable span rested. The first crack was noticed after 14 MGT of HAL traffic. As the riser plate was also attached to the base plate with huck bolts, no weld repair was deemed necessary. The manufacturer has indicated that in future versions of this design, the riser plate will be attached using only huck bolts, no welds. After continued traffic, the weld cracks propagated into the base plate. Weld repairs were then made to the base plate and cracked welds. After further tonnage accumulation, the welds holding the wedge guides for the movable span tip rails also cracked at the base plate. These weld cracks were repaired promptly.

After 106 MGT of HAL traffic, this bridge joint was removed from service. Reasons for removal included repeated cracking of the base plates, deterioration of the rail surface, increasing impact forces, and increasing maintenance demand. Maintenance demand included repair of bridge walkways and handrails that broke or became loose because of the impacts. The deck hook bolt fasteners on the timber ties supporting the bridge joint also required frequent tightening, in spite of using locking clips and double nuts. Hook bolts were frequently breaking as well, presumably because of the high impact environment. The maintenance demand had grown to the point where some type of maintenance was required almost every day of train operation. When the joint was new, the required maintenance was less than once per week (5 to 8 MGT) during train operations.

Figure 3 shows a comparison of bridge joint life at FAST. Joints were removed previously for similar reasons.[2]

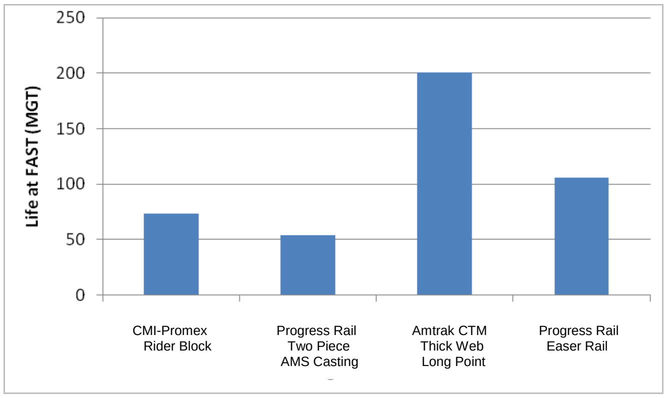

Figure 3. Comparison of Bridge Joint Life at FAST

Dynamic Forces

TTCI quantified dynamic impact forces over the movable bridge joint using two different methods: (1) measured vehicle performance exceptions using TTCI's instrumented freight car (IFC) and (2) wheel/rail forces measured using instrumented wheelsets. The IFC is typically part of the test train at FAST, thus measurements are available throughout the life of the movable bridge joint. The instrumented wheelset test train was run only near the end of the life of the joint.

When the joint was new, the IFC noted exceptions near the movable bridge joint only while operating in the direction from movable span to fixed span (in the clockwise direction around the loop). No exceptions were noted while operating in the direction from fixed span to movable span. The only exception parameter was a truck side frame vertical acceleration exceeding 4 g.

When the joint was worn, the IFC noted exceptions near the movable bridge joint while operating in both directions. In addition to the truck side frame vertical acceleration exceptions, there were exceptions to the truck side frame lateral accelerations exceeding 3 g. Figure 4 compares the exceptions for the joint in both the new and worn conditions. In some cases, more than one exception was noted per train pass, indicating that sometimes both truck side frames experienced high vertical accelerations, or that high accelerations were experienced in both vertical and lateral directions. As expected, the impact acceleration values, both average and maximum, were greater in the worn condition.

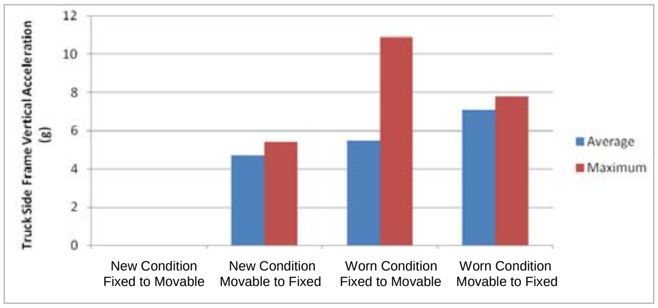

Figure 4. Vertical Acceleration Levels over Bridge Joint for New and Worn Conditions and Both Directions of Travel

TTCI used a pair of instrumented wheelsets to measure the vertical wheel/rail forces under a typical HAL car as it ran over the movable bridge joint. The instrumented wheelset measurements were performed near the end of the service of the joint. The highest force recorded was 72,000 pounds, which is 83 percent higher than the nominal static wheel load of 39,375 pounds. Chapter 15 of the American Railway Engineering and Maintenance-of-Way Association's *Manual for Railway Engineering* recommends designing for an impact of 100 percent in locations where movable bridge joints are used.[3] This recommendation seems reasonable in light of the data presented here.

Effects on Bridge Span

As with testing of previous bridge joints at FAST, the dynamic impact forces from the train passing over the joint resulted in an increased maintenance demand for the bridge itself. New cracks appeared in two welds on the 55-foot welded girder span (fixed span). An existing weld crack in a brace-to-stiffener connection propagated through the entire stiffener.

No problems were noted with the 55.5-foot vintage steel span (movable) that could be attributed to the presence of the bridge joint. It is likely that the riveted fabrication is much more tolerant of the impact and fatigue loadings from the bridge joint as compared to the adjacent welded span. It must also be noted that all of the rail surface transition areas of the joint were on the 65-foot welded span (fixed), so the 55.5-foot riveted span (movable) was likely not subjected to impacts as extreme as those on the 65-foot welded span.

RECOMMENDATIONS

Reduce wheel elevation changes across the joint. The longitudinal hump in the easer rail was intended to ensure that all wheels are supported across the joint and to provide for some wear/metal flow of this rail.

The cross section of the easer rail should also be adjusted. The only portion of a wheel that will be in contact with the easer rail is the field side of the tread. A 1:20 profile, which will match the wheel tread design profile, will reduce metal flow on the corner of the rail. This flow can affect joint performance by changing track gage and interfering with bridge span movement.

Further study of pad design for the joints is needed. A pad with more damping will likely reduce impacts at the joint. The chosen pad must survive for the life of the joints.

Bolted rather than welded fabrications of joints are recommended for the plate work and braces. These will be more tolerant of impact and fatigue loadings.

ACKNOWLEDGEMENTS

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