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Preliminary Results of Prototype Insulated Joint Tests at the Facility for Accelerated Service Testing

SUMMARY

As part of the Association of American Railroads (AAR) Strategic Research Initiatives Program, Transportation Technology Center, Inc. (TTCI), a wholly owned subsidiary of the AAR, in Pueblo, Colorado, is working with the Federal Railroad Administration (FRA), suppliers, and railroad companies to improve the service life of bonded insulated joints (IJs) in a heavy axle load environment at the Facility for Accelerated Service Testing (FAST).

Twenty-eight prototype IJs are being tested at FAST. Prototype IJs were installed in-track by TTCI to examine the extent of improvement in IJ performance and service life using improved conventional and miter cut designs. While long-term performance of these joints remains to be determined, preliminary conclusions made are favorable.

Component durability: Flexible material in and around the end post area may reduce adhesive cracking. No significant difference in the performance of bolted versus Huck® fasteners was observed. Higher metal flow was observed at the ends of lower hardness rails.

Improved foundations and reduced deflections: Wider wood ties, wood frame ties, and closely spaced wood ties appear to have reduced ballast surfacing requirements under IJs. IJ deflections may be reduced by up to 30 percent by doubling the modulus of current joint bars. Higher modulus bars will also increase fatigue strength of joint bars.

Reduced impacts: Due to a smoother wheel transition across the end post, miter cut joints imparted 50 percent lower dynamic loads to rail as compared to conventional IJs. These dynamic loads are comparable to open track. A 3/16-inch rail gap for conventional butt joints is optimal for reducing impacts and metal flow. Solid sawn wood ties provide greater damping as compared to composite wood ties and concrete ties with rubber pads.

Reduced longitudinal stresses: Miter cut joints have 40 percent higher resistance to longitudinal loads than conventional IJs.

Figure 1. Miter Cut Insulated Joint.

BACKGROUND

As part of the AAR Strategic Research Initiatives Program, TTCI is working with FRA, suppliers, and railroad companies to improve the service life of bonded IJs in a heavy axle load (HAL) environment.

Twenty-eight prototype IJs are being tested at FAST; twelve conventional joints with improved foundations; 11 improved IJ components and five miter cut joints. Accumulated tonnage on all prototypes is still below typical 400 MGT service life of IJs at FAST.

Though most of the data collected from the prototype IJs was quantitative; some qualitative data was also collected, including vertical IJ deflections, damping characteristics of cross-ties, rail metal flow, rail hardness, and electrical resistance. Qualitative data included visual inspections of adhesive, ballast, Huck® fasteners and bolts, end post, and insulating material.

Compared to conventional IJs, miter cut joints reduced the dynamic load by 50 percent, comparable to open track measurements. The miter cut joint provides 33 percent higher resistance to longitudinal forces. Due to longer running surfaces, miter cut joints tend to develop more metal flow. Different corner radii were tested to minimize metal flow.

Discontinuity in rail creates higher impacts; therefore, IJ foundations are prone to higher rates of degradation than open track. Increasing the bearing area may improve load transfer, thereby reducing ballast degradation. For this purpose, wider ties, wood tie frames, and closely spaced ties are being tested. These configurations have reduced the surfacing requirements of conventional IJs.

Shear stresses are particularly higher at the end post and cause the epoxy to crack. To counter this issue, a flexible rail liner near the end post was used. This approach has reduced adhesive cracking. Another approach to reduce adhesive stresses is to use high modulus bars, tie-plates, and longer joint bars. In addition to reducing adhesive stresses, this approach also reduced IJ deflections.

Some prototype IJs were removed from track for rail quality issues, but none showed signs of epoxy distress. As foundation and epoxy issues are resolved, running surface issues become important.

COMPONENT DURABILITY

Flexible Materials

Corrosion at or around the end post is a typical problem with current suspended butt IJ designs.[1] Corrosion starts at the end post and makes its way toward the joint ends. Modeling suggests that adhesive stresses may be as high as 6,000 pounds per square inch around end posts, mainly due to shear lag.[2] Research shows that no commercially available structural adhesives can hold up to these stresses. It appears that once the joint is loaded, adhesive cracks develop, then moisture penetrates the joint and corrodes the metal.

The steel surface may be protected against corrosion by providing surface treatment or using flexible material. The former has limitations due to different rail steel chemistry from vendors and adhesion characteristics of surface treatments. The latter does not have such limitations.

In this technique, adding flexibility in the center of the joint was used to relieve epoxy shear stresses. A prototype joint with a flexible material was removed from track, due to a crushing railhead after 300 MGT. An autopsy of the railhead showed no adhesive cracking at or near the end post (Figure 2). Two similar prototypes are still in track and show no signs of corrosion.

Figure 2. Autopsy of IJ Shows Benefit of using Flexible Material at End Post. Arrows Show No Rust at End Post

Fastener Types

Experience has shown that the preload is not uniform in all IJ bolts and that the bolts may become loose due to vibrations; therefore, Huck® fasteners are being used in IJs instead of bolts.

Theoretically, using Huck® fasteners should not have an advantage over using bolts, because the uniformity in bolt preload may be controlled by quality control and once hardened, the adhesive provides resistance against bolt loosening.

To test the theory, conventional joints with Huck® fasteners and bolts made with Grade 8 steel were installed. The test accumulated 200 MGT. To date, no practical performance difference was observed.

Rail Quality

Figure 3a shows an IJ removed after 300 MGT due to a railhead crushing. This is generally caused by hairline cracks in cold metal flow. When metal flow is not ground properly and timely, these cracks grow over time and large chunks of metal start coming off the railhead. Figure 3b shows an IJ removed after 200 MGT due to chipping at the rail end and gage corners. Rolling contact fatigue and metal flow appear to be the cause. It appears that improved quality control and more durable materials have improved the performance of the prototypes, but the service life is limited by rail quality.

Figure 3a. Railhead Crushing, Prototype Removed after 300 MGT.

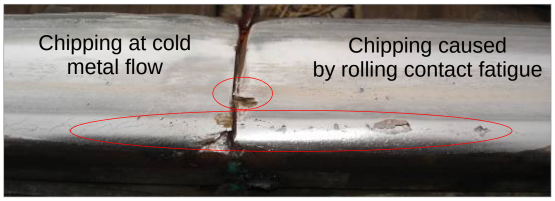

Figure 3b. Chipping at Rail End and Gage Corner, Prototype Removed after 200 MGT.

FOUNDATIONS AND REDUCED DEFLECTIONS

Joint Bars

Conventional joint bars are prone to fatigue cracks, a major cause of failure (Figure 4). Higher modulus bars are expected to increase joint bar fatigue strength. High modulus joint bars may also reduce deflections. Five joints with two different joint bar configurations are in test (Figure 5). The moment of inertia of these bars is 1.25 to 2 times that of the rail. After 300 MGT, no cracked or broken bars were observed.

Figure 4. Joint Bar with Fatigue Crack. Removed after 75

Figure 6 compares the net track deflections from an empty car (49.9 kips) and locomotive (166.8 kips). When compared with a conventional joint, the high modulus bars with moment of inertia of 1.25*RE do not show significant changes in deflection; however, high modulus bars with moment of inertia of 2*RE experienced 33 percent less deflection than 1.25*RE.

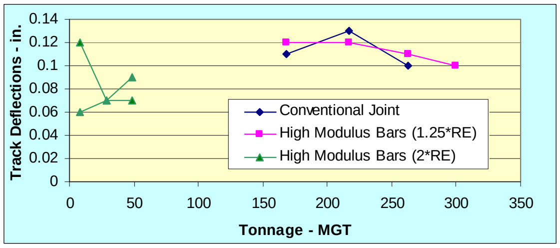

Figure 6. Net Track Deflections under Empty Car and Locomotive.

Tie Configurations

For optimum IJ performance, track deflection should be in the range of 0.15 to 0.25 inch.[3] A number of different techniques were tested to provide and maintain this level of track stiffness; i.e., 12-inch-wide wood ties, 14-inch center-to-center standard wood ties, and wood-frame ties. These configurations provide 10 to 25 percent more bearing area.

These configurations are expected to reduce the bearing stresses in ballast by the same amount. As a result, there will be a reduction in ballast degradation and track deflection, Figure 7 compares the track deflection of different tie configurations. These configurations have reduced the ballast surfacing requirements of IJs.

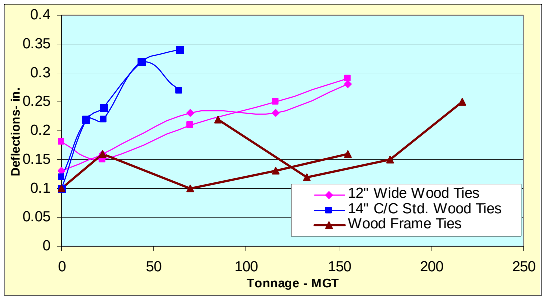

Figure 7. Track Deflections with Different Tie Configurations 32-kip Static Load.

REDUCED IMPACTS

Damping Characteristics

Dynamic data was collected from accelerometers buried in the subgrade close to standard wood ties, Parallam ties, and concrete ties with rubber pads. Data from accelerometers are a good indicator of damping characteristics of the structure. Higher values show lower damping.

Ballast thickness was the same in all the cases. The vertical and horizontal distance of the accelerometers from the ties was also identical. Figure 8 shows that wood ties have the lowest acceleration values or highest damping. This suggests that wider wood ties may further increase the damping of track structure.

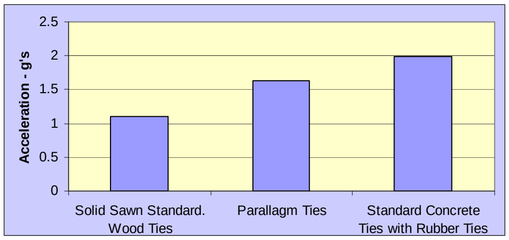

Figure 8. Damping Characteristics of Tie Materials.

Optimum Rail End-Gap

The end gaps in current conventional joints vary from 3/16 to 3/8 inch. Larger gaps need less metal flow grinding due to longer maintenance periods. Small gaps are required to reduce the impacts and allow smooth wheel transition.

To find the optimum rail end gap, 1-inch-deep slots of varying widths were made in smooth rail. Metal flow and vertical loads were measured at different intervals up to 55 MGT. As Figure 9 shows, the metal flow from a 1/4-inch gap was the highest. Dynamic loads were comparatively higher at 1/4 inch. At a 3/16-inch gap, the trade-off between impact and metal flow is balanced.

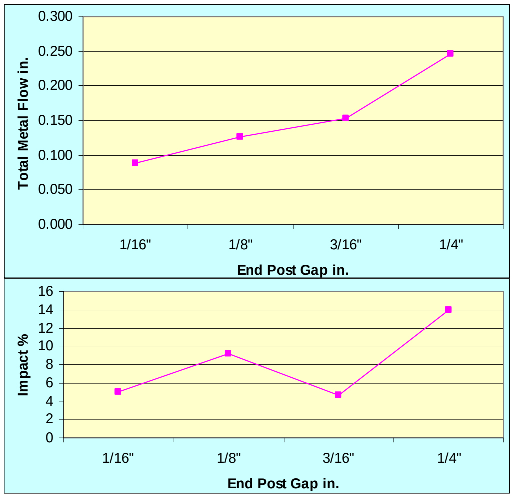

Figure 9. Total Metal Ground at Rail Gaps after 55 MGT.

Miter Cut Joints – Next Generation IJs

The miter cut design efficiently reduces impacts (Figure 10), has superior resistance to longitudinal loads, and is stiffer than conventional IJs. The only design issue was metal flow along the running surface, which suggests the use of premium head hardened rail with superior surface and depth of hardening. Metal flow is minimized by changing running surface longitudinal and cross-section profiles.

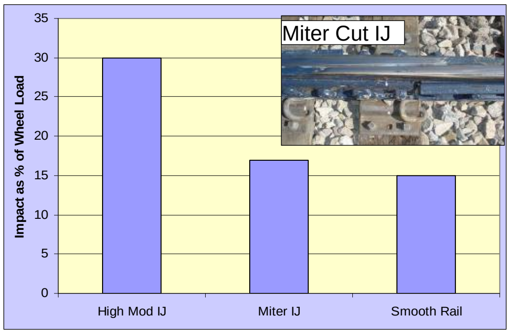

Figure 10. Comparison of Wheel Impacts from Wheels (top) Metal Flow at End Post Gaps, (bottom) Impacts from End Post Gaps.

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