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Preliminary Results of Prototype Insulated Joint Tests at FAST

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Summary

Prototype insulated joints (IJs) were installed in track at the Facility for Accelerated Service Testing 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, the following preliminary conclusions have been made:

- Component Durability
 - Flexible material in and around the end post area can reduce adhesive cracking.
 - No significant difference in the performance of bolted versus Huck[®] fasteners has been observed.
 - Lower hardness rails have higher metal flow at rail ends, which suggests use of premium head hardened rail for IJ plugs.
- Improved Foundations/Reduced Deflections
 - Wider wood ties, wood frame ties, and closely spaced wood ties appear to have reduced ballast surfacing requirements under IJs.
 - IJ deflections can be reduced up to 30 percent by doubling the modulus of current joint bars. In addition, higher modulus bars will also increase fatigue strength of joint bars.
 - Supports for suspended IJs, where the end post is over a ballast crib, such as two-tie plates, are also helpful in reducing the deflections during initial service life.
 - A supported foundation, where the end post is over a crosstie, provides greater benefit in terms of lower deflections as compared to suspended joint on two-tie plates. A three-tie plate is often used on supported foundations to further reduce IJ deflections.
- 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 what is measured in 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.



INTRODUCTION AND CONCLUSIONS

As part of the Association of American Railroads (AAR) Strategic Research Initiatives Program, Transportation Technology Center, Inc. is working with suppliers and railroad companies to improve the service life of bonded IJs in heavy axle load (HAL) environment.

Twenty-eight prototype IJs are being tested. Twelve are conventional joints with improved foundations; 11 have improved IJ components; and 5 are miter cut joints. Accumulated tonnage on all prototypes is still below typical 400 MGT service life of IJs at the Facility for Accelerated Service Testing. Although long-term performance remains to be determined, preliminary results and findings are favorable.

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

Miter cut joints have reduced the dynamic load by 50 percent as compared to conventional IJs. These loads are comparable to what is measured in open track. Also, the miter cut joint provides 33 percent higher resistance to longitudinal forces by having a third epoxy surface. Due to longer running surfaces, miter cut joints tend to develop more metal flow. Different corner radii are being 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 can 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 that, 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. Besides reducing adhesive stresses, this approach has also reduced the IJ deflections.

Some prototype IJs were removed from track due to rail quality issues, but none show signs of epoxy distress. As foundation and epoxy issues are resolved, running surface issues will become more important.

COMPONENT DURABILITY

Flexible Materials

Corrosion at or around the end post is a typical problem with the current suspended butt IJ designs.¹ It starts at the end post and makes its way towards the joint ends. Modeling suggests that adhesive stresses can be as high as 6000 psi around end posts, mainly due to shear lag.² A literature search shows that no commercially available structural adhesives can hold up to these stresses. It seems that once the joint is loaded, the

adhesive cracks develop. Moisture then penetrates and corrodes the metal.

The steel surface can 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 is 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 showed no adhesive cracking at or near the end post (see Figure 1). Two similar prototypes are still in track and show no signs of corrosion.

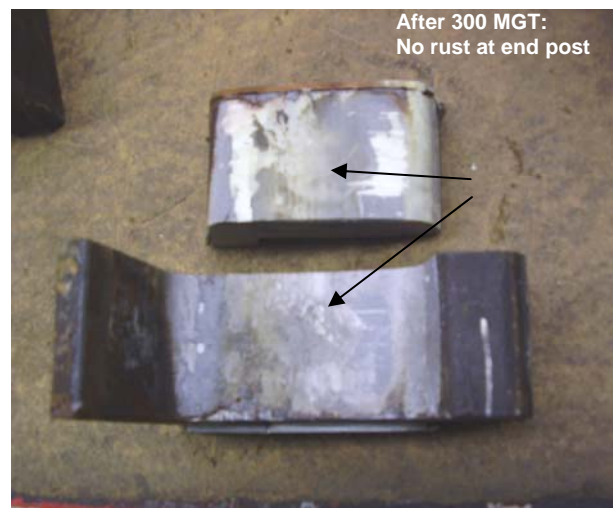


Figure 1. Autopsy of IJ shows Benefit of using Flexible Material at End Post

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 can be controlled by quality control, and, once hardened, the adhesive provides resistance against bolt loosening.

In order to test the theory, conventional joints with Huck® fasteners and bolts were installed. Both are Grade 8 steel. The test has accumulated 200 MGT. So far, no practical difference has been observed in their performance.

Rail Quality

Figure 2a 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 2b shows an IJ removed after 200 MGT due to chipping at the rail end and gage corners. Rolling contact fatigue and metal flow appears to be the cause.

It appears that improved quality control and more durable materials have improved the performance of prototypes. But the service life is limited by rail quality.



Figure 2a. Railhead Crushing, Prototype Removed after 300 MGT

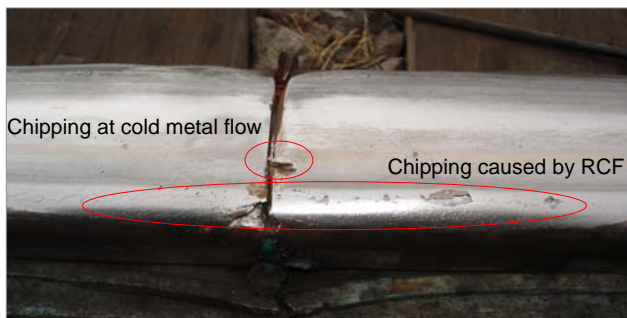


Figure 2b. Chipping at Rail End and Gage Corner, Prototype Removed after 200 MGT

FOUNDATIONS AND REDUCED DEFLECTIONS

Joint Bars

Conventional joint bars are prone to fatigue cracks, which is a major cause of their failure (see Figure 3). Higher modulus bars are expected to increase the fatigue strength of joint bars. In addition, high modulus joint bars can also reduce deflections. Five joints with two different joint bar configurations are in test (see Figure 4). The moment of inertia of these bars is 1.25 to 2 times the rail. No cracked or broken bars have been observed after 300 MGT service life.

Figure 5 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 does 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 3. Joint Bar with Fatigue Crack. Removed after 75 MGT



Figure 4 (top) High Modulus Joint Bars 2*RE and (bottom) 1.25*RE

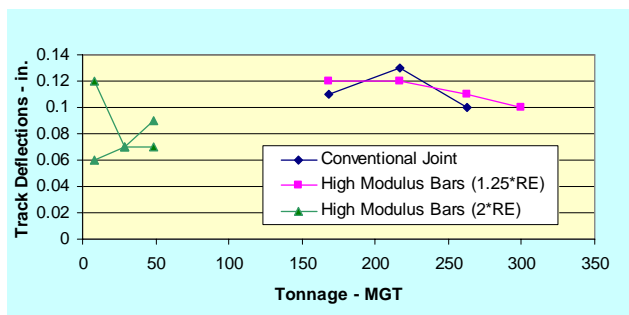


Figure 5. Net Track Deflections under Empty Car and Locomotive

Tie Configurations

For optimum IJ performance, track deflection should be in the range of 0.15 inch to 0.25 inch.³ A number of different techniques are being 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. All 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 6 compares the track deflection of different tie configurations. These configurations have reduced the ballast surfacing requirements of IJs.

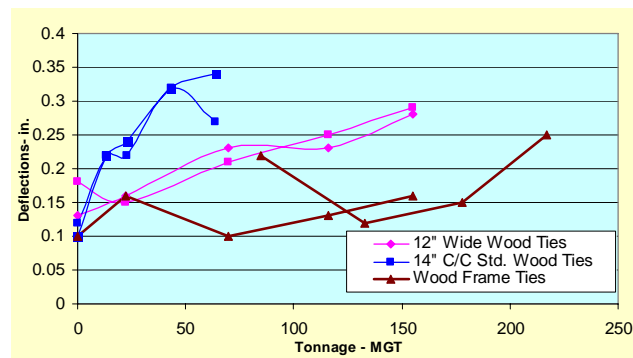


Figure 6. Track Deflections with Different Tie Configurations 32-kip Static Load

REDUCED IMPACTS
Damping Characteristics

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

Ballast thickness was the same in all the cases. The vertical and horizontal distance of the accelerometers from the ties was also identical. In Figure 7, a comparison for three cases 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.

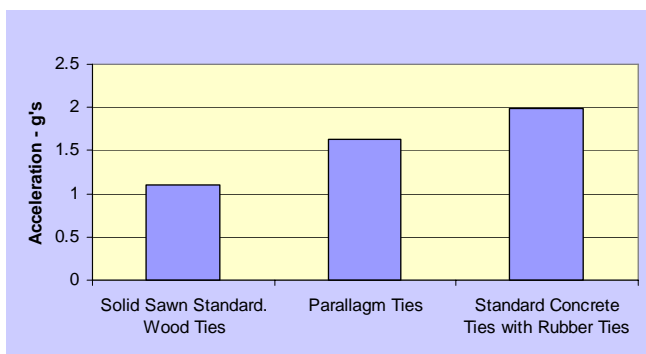


Figure 7. Damping Characteristics of Tie Materials

Optimum Rail End-Gap

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

In order 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 8 shows, the metal flow from a 1/4-inch gap was the highest. Also, dynamic loads were comparatively higher at 1/4 inch. It appears that at a 3/16-inch gap, the trade-off between impact and metal flow is balanced.

Miter Cut Joints – Next Generation IJs

The miter cut design is efficient in reducing impacts (Figure 9). It also has a superior resistance to longitudinal loads and is much stiffer than the conventional IJ. The only design issue is metal flow along the running surface, which suggests the use of premium head hardened rail with superior surface and depth of hardening. Currently, metal flow is minimized by changing running surface longitudinal and cross-section profiles.

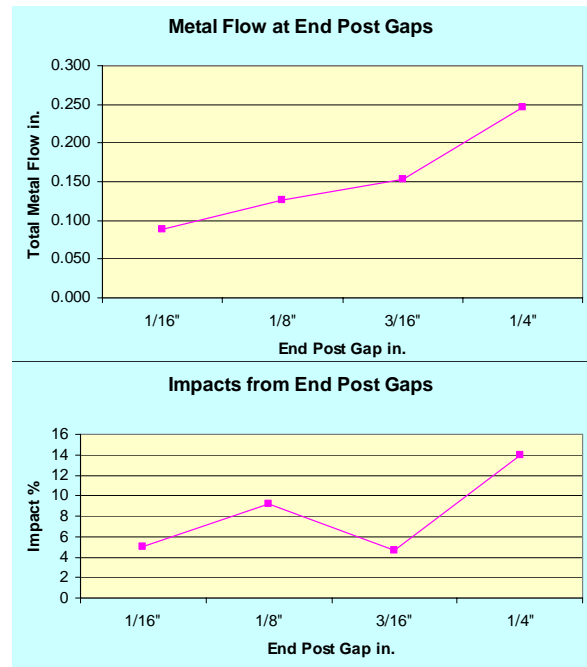


Figure 8. Total Metal Ground at Rail Gaps after 55 MGT

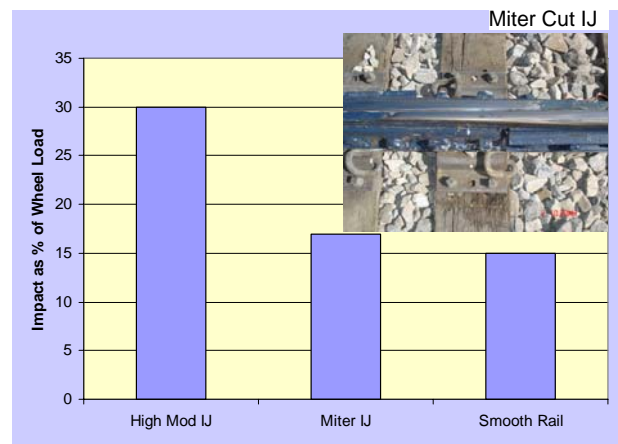


Figure 9. Comparison of Wheel Impacts from Wheels

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