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Rail Joint Installation and Maintenance Recommended Practices

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Summary

Under sponsorship of the Association of American Railroads' Strategic Research Initiatives (SRI) Program, Transportation Technology Center, Inc., (TTCI) has compiled the best practices for rail joint installation, maintenance, and rail stress management. Rail joints, especially bonded insulated joints (IJs), are major causes of signaled track service failures. These components are relatively short lived, difficult to inspect, and tend to fail electrically without much advance indication.

This SRI project is working to improve average rail joint service life by improving the design of the rail joint and supporting track structure. Bonded IJ design work has been successful in increasing service life in heavy axle load service.[1] The work described in this *Technology Digest* can be applied to these new designs or existing designs of joints. The best practices described were collected from observation of current operations on BNSF Railway and Union Pacific and supplemented with analysis and controlled experiments by TTCI. Findings from the study include:

- Installation best practices:
  - Direct support foundations (i.e., a crosstie under the rail ends) will reduce maximum stresses in the joint. This configuration may not be possible for temporary joints, but is very beneficial for bonded IJs.
  - The practice of installing IJs on track panels is recommended. This allows for foundation improvements when the new joints are installed.
  - Adding track damping to high dynamic load areas, such as rail joints, will prolong their service life.
- Maintenance:
  - Maintaining surface is key to good joint performance.
  - Vertical slotting of rail joints (especially IJs) will increase average service life. More training on proper techniques and development of fixturing to properly guide the grinding tool is needed.
- Rail Stress Management:
  - Bonded IJs may be treated like welds for purposes of rail stress management.
  - Additional anchoring around rail joints (e.g., anchoring every tie in wood tie track) is beneficial in resisting rail slippage in mechanical and debonded epoxied IJs. The additional anchoring will also minimize the rail end gaps, if the joint has a pull-apart.

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INTRODUCTION

Rail joints are special trackwork features that require somewhat different installation, maintenance, and stress management policies than open track. IJs occur at signal control points and may be subject to different train operations than other locations. The structure of rail joints also makes them weaker than continuous welded rail track. Thus, additional considerations are necessary when installing and maintaining rail joints.

This *Technology Digest* discusses the special considerations for rail joints and recommends best practices for installation and maintenance of rail joints.

INSTALLATION

The configuration of the foundation for rail joints is of utmost importance for extending service life of joints in heavy axle load service. For all joint designs, a supported foundation is superior to a suspended foundation for purposes of maximizing service life. A supported foundation is one that has a crosstie under the endpost of the joint. Traditionally, suspended joints (with endpost over a ballast crib) are used to ensure that tie plates will not cause an electrical short. With the advent of better insulator materials and application technologies, a reliable insulating bearing plate can now be used with supported foundation insulated joints.

The most significant advantage of a supported foundation is the reduced maximum shear stresses in the joint.[2] For epoxied joints, the reduction is in the epoxy layer, near the endpost. For non-epoxied joints, the reduction is in the compression (contact) surfaces of the joint and rail-bar fasteners.

In epoxied joints, tensile longitudinal forces and supported foundation bending forces tend to be additive near the endpost. This is where the maximum epoxy shear stresses will occur. If the joint has a supported foundation; however, the tensile longitudinal forces will tend to counteract the live load bending and shear stresses near the endpost. Thus, a supported joint should be able to carry more load during cold weather than will a joint on a suspended foundation.

Table 1 shows the relative effects of various components on IJ epoxy stresses. Note that a supported foundation provides a larger benefit (up to 30 percent reduction in shear stress) as compared to other design changes. Ironically, increasing joint bar section modulus, while keeping all other design elements the same, will increase epoxy shear stresses. The joint will have less deflection, but the stresses in the weakest component, the epoxy, will be higher.

Table 1. Effects of Component Changes on Maximum IJ Epoxy Stresses

Component	Change	Base Case	Effect on Epoxy Stress	Comments
Crossties	11-inch width	9-inch width	-10 % shear, 0 % peel	Deflections are lower
Crossties	Supported	Suspended	0 % to -30 % shear	Depends on longitudinal stress state
Joint Bars	48-inch length	36-inch length	-20 % shear, + 7 % peel	Deflections are lower
Joint Bars	2, 3 x I	I = 48-inch	+73, 110 % shear, +79, 110 % peel	Deflections are lower

The use of track panels for installation of IJs has been adopted by a major western railroad. They install a pair of IJs and new crossties as a pane, as Figure 1 shows. This practice also allows the replacement and compaction of ballast prior to operations on the new IJs. The panels are also configured to provide improved tie support with wider ties under the IJ.

Figure 1. Installation of IJs on Track Panels

CONSIDERATIONS FOR NONINSULATED JOINTS

Mechanical joints are often temporary joints in track. If the intent is to replace the joint with a thermite weld, then a suspended foundation is preferable. The base of a thermite weld would have to be ground flush with the rail to accept a tie plate.

Compromise joints, where the rail section changes, also should be placed on suspended foundations.

FOUNDATION DYNAMIC CHARACTERISTICS

A rail joint foundation should accommodate the unique characteristics of a rail joint. The rail joint is a discontinuity in the rail running surface. As such, it is likely to generate dynamic loads. Optimal track stiffness and damping properties can help mitigate the effects of dynamic loading and joint deflection that lead to joint degradation. Higher foundation stiffness is often needed to compensate for the lower stiffness of the joint as compared to the surrounding rail. Uniformity of support is important to minimize rail to bar relative movement.

Adding damping to the foundation will allow the joint to survive larger dynamic loads. This can be done by adding resilient pads to concrete ties or using wood ties in concrete tie track. Figure 2 shows the effects of damping (as shown with different tie types) on dynamic forces. The traffic and IJ designs for each case are the same. The lower accelerations show the effects of the foundation on IJ dynamic performance. The foundations with more damping have lower accelerations. Transitioning from open track to higher damping track must be gradual enough to avoid creating an additional discontinuity at each end of the IJ.

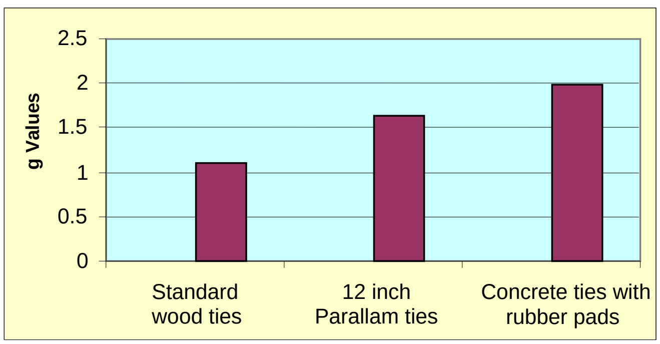

Figure 2. Effect of Damping on Dynamic Forces, Peak-to-peak Values

Lateral stability is another consideration for rail joints. These locations can be near control points in track, and thus may have higher longitudinal forces. Lateral stability can be provided by use of larger crossties (length, cross section, or both) or larger ballast shoulder. Nonstandard, low-profile clips that do not touch the joint bars are needed for IJs. While several prototypes show promise, no definitive favorite has emerged.

Installation of IJs on track panels can provide a longer service life for each IJ by assuring the condition of the foundation. Installation of a track panel allows the railroad to replace or even reinforce the ballast layer prior to installation of the new IJs.

MAINTENANCE

Preventive maintenance can greatly affect the life of the rail joint. The most important maintenance items are:

- Track surface maintenance
- Running surface maintenance

The typical bonded IJ is less stiff (vertically) than the surrounding rail. Since the foundation is the same as the rest of the track and the IJ may generate dynamic loads from the running surface gap, the joint will require surfacing more often.

Rail flow at the endpost should be removed to prevent joint shorting and rail end cracking. The process of slot grinding a joint is too variable due to lack of proper equipment and training of welders. Currently, a handheld grinding wheel is used to grind surface metal.

Figure 3 shows an example of poor slotting practice. The rail on both sides of the joint has been sloped down to the endpost. This leaves a 3- to 4-inch low spot that will generate high dynamic forces. We speculate that the welder was reluctant to remove any of the endpost, and thus created a dynamically worse situation.

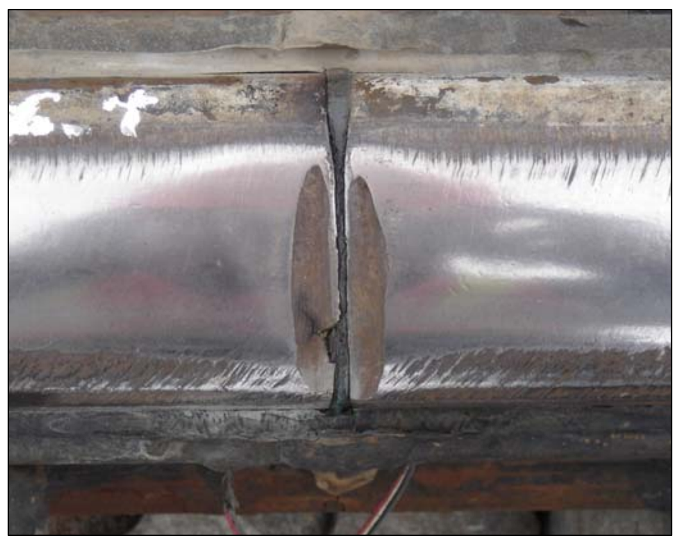

Figure 3. Less than Optimal Joint Slotting

A semi-automated system is needed to ensure that the flowed metal is removed, while minimizing the effect on running surface profile. This suggests a fixture that will hold the grinding wheel vertical and limit the depth of cut.

LONGITUDINAL STRESS MANAGEMENT

The effects of rail longitudinal forces on IJ epoxy stress were analyzed to illustrate the effects of installation and rail stress management practices on IJ service life. Table 2 shows the maximum epoxy shear stresses from two cases.[2] The first has no longitudinal force in the rail. The second has 200,000-pound tensile longitudinal force in the rail, which corresponds to winter conditions in mainline track.

Table 2. Effect of Rail Longitudinal Force on Maximum Epoxy Stress

Loading Case	Maximum Epoxy Stress (pounds per square inch)	Location of Maximum Epoxy Stress	Comments
No longitudinal force, 33,000-pound loads	5,430	Top, center of joint	
200,000-pound longitudinal force, 33,000-pound loads	6,440	Bottom, center of joint	Lower temperatures may also embrittle the epoxy and stiffen the foundation

From Table 2, it can be surmised that lowering the average and maximum tensile force in the rail will reduce the epoxy shear stresses. Lower epoxy stresses will result in a longer service life for the joint.

Consideration should be given to managing the rail neutral temperature at IJ locations by balancing the risk of track buckling against the harmful effects of high tensile forces on rail and IJ components. When stressing the rail during an IJ installation, care should be taken to avoid over-tensioning the rail and creating an unnecessarily high neutral temperature, especially if a desirable, in-track welder is being used. A conservative rule-of-thumb for track buckling strength is 60 degrees Fahrenheit above the neutral temperature. This value can be used to establish an optimal neutral temperature condition that minimizes tension to the extent possible without compromising the lateral stability of the track.

Longitudinal restraint of the rail at IJ locations is another important consideration. A bonded IJ that is structurally sound is basically no different than a weld. In this case, once the rail is fully constrained against thermal expansion, as is normally provided with a standard rail anchor pattern (every-other tie box anchored or every tie fastened with elastic fasteners), additional anchoring will not change; i.e., reduce, the longitudinal thermal forces that develop at the joint. However, when the bonding material of the joint begins to fail, additional anchors will resist slippage of the rail within the joint and can prolong its service life. If the joint fails completely and the rail ends pull-apart, additional rail anchors will obviously minimize the gap size compared to the standard pattern.

Additional anchoring is also necessary to control the longitudinal rail movement, or rail creep, that is caused by train traction and braking forces in addition to temperature changes. This train induced rail movement can significantly reposition one IJ relative to the IJ on the other rail, causing the allowable stagger distance to be exceeded. Box anchoring every wood tie 200 to 300 feet each side of the IJ is a fairly typical, but not universal, practice for mainline track. Some railroads also selectively add rail anchors to ties with elastic fasteners to increase the longitudinal restraint.

CONCLUSION

The effects of installation, maintenance, and rail longitudinal stress management on rail joint service life can be significant. Relatively small changes to foundation design and running surface maintenance are suggested.

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