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# The Historical Evolution of Standard Rail Joint Bars

Sabri Cakdi, Muhammad N. Akhtar, and David D. Davis

## Summary

A literature search was conducted to understand how the current standard joint bar designs evolved over the years. The main source of this search was the annual conference proceedings of the American Railway Engineering Association (AREA) and its successor organization American Railway Engineering and Maintenance of Way Association (AREMA). The results of the literature search will be used to help with the new joint bar design.

The literature review showed that railroads face similar problems today with joint bars that were faced by railroads in the 20th century. In addition, joint bar cracking and breaking in continuously welded rail may have more severe consequences than in jointed rail. The Association of American Railroads' Strategic Research Initiatives Program intends to design a newer joint bar profile that will have more resistance to rail thermal expansion and contraction.

During the late 19th and early 20th centuries, the commonly used joint bar cross sections were mostly symmetrical and simple in geometric design. To reduce cracking and breaking of joint bars, several unsymmetrical joint bars were designed that had cross sections similar to rail. These bars had long toes (angles), and some had tie plates as integral plates, making the cross section almost double the size compared to symmetrical joint bar designs.

Over several years of theoretical and experimental study, the railroads concluded that symmetrical joint bars perform similarly to unsymmetrical angled (long-toe type) designs, with considerably lower weight. This was due to the fact that under vertical loads joint bars with long toes bend laterally as well as vertically. On the basis of this finding, the AREA committee on track stresses recommended a standard symmetrical joint bar design.

In the 1940s, a detailed survey concluded that AREA standard design joint bars reduced the failures that were common with the unsymmetrical designs. It was further noted that many of the joint bar problems pertained strictly to the initial installation and maintenance of the joints, and not to the design or specifications. That, and the introduction of rail welding, may be why no significant research and development was conducted since then to improve the joint bar design.

The railroads also learned from experience that where the railhead made contact with a joint bar was one of the possible sources of railhead chipping, which was a common problem with rails during this time. A head-free feature was added to the basic joint bar design, which is the current standard design. In this design, the joint bar contacts the rail in the head-web fillet radius.



**INTRODUCTION**

“Joint bars,” “fish plates,” or “splice bars” are the terms for track components used to join two rails. Joint bars may be categorized into insulated joint bars, standard joint bars, compromised joint bars, and strap joint bars. As the name suggests, insulated joint bars are used to make insulated joints for purposes of dividing the track into electrical circuits for signal controls. Standard joint bars are used to join two rail lengths permanently or temporarily. Compromised joint bars are installed to join rails of different sections. Strap joint bars are used at welds or when a defect is present in the rail as a precaution against failure. The current literature search focuses only on standard joint bars.

This digest reviews various features of current joint bars and why and how they were incorporated. The results of the research will be used to help with a new joint bar design. An important performance issue since the early 20th century has been gouging on the top surface of the joint bars due to railhead contact. Gouging was believed to be the source of crack initiation. Easement was introduced on the top of the joint bar to avoid this contact, but rolling load testing conducted in the laboratory showed it reduced but did not eliminate crack initiation.<sup>1</sup>

Extensive theoretical and experimental work conducted under the direction of AREA determined that matching the inertial moment of joint bars to the rail does not necessarily increase its strength, because of lateral bending of the unsupported bottom flange. The same study recommended a joint bar design that has been the industry standard since then, with minor changes over time.

The thin joint bar web of the standard design provides wedging action due to “springiness” (i.e., bending about the long axis). Once all the bolts are tightened, the joint bar does not come off even after the bolts are removed. The joint bar needs to be hammered out. This wedging action stiffens the joint when there is some torque loss in the bolts. However, unit contact stress at the small contact area due to wedging action causes excessive metal flow, and is most likely responsible for joint bar crack initiation.<sup>2</sup>

**Symmetrical Designs**

Symmetrical designs were the most commonly used joint bar shapes during the late 19th and early 20th centuries. Various forms of prismatic bars were used with sections that had the common property of being symmetrical with respect to a horizontal axis through the center of gravity. Top and bottom section moduli were similar. Some joint bar designs could be installed upside down due to having the same contact profile on top and on bottom (Figure 1).

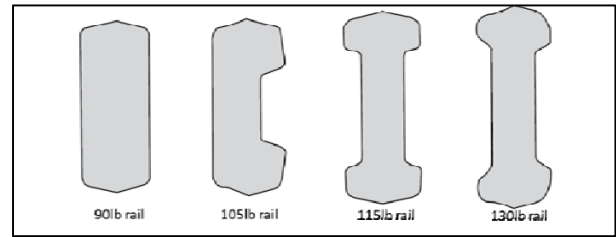


Figure 1. Symmetrical Joint Bar Designs

In the early 1900s, many failures at the joint were attributed to weak joint bars. In order to reduce joint bar failures, designers and manufacturers concentrated efforts on unsymmetrical joint bar designs making joint bar cross section similar to rail.

**Unsymmetrical Designs**

Figure 2 shows various unsymmetrical joint bar designs that were commonly used during the first few decades of the 20th century. The angled (or long-toed) joint bar extended beyond the edge of the rail base with slots to allow for spike installation. The notable feature of this joint bar design was its larger bottom section, which was approximately doubled that of the top section modulus. As a result, very few joint bar cracks or breaks were reported that started from the bottom. However, cracks starting from the top of the joint bar, where the railhead made contact with the joint bar, were common. This is probably why an easement was recommended on the top of the joint bar. This joint bar had spike holes that were punched in the base edges, which were undesirable. Several railroads reported cracks that often started at this location and broke the joint bars.

In the continuous joint design, the joint bar was extended under the rail base. Thus, the joint had an integral tie plate, which was also called rail base joint, rail bridge joint, etc. The extended portion had holes for spikes and was used as a tie plate. The alignment and location of the joint was assured and stable because joint bars were attached to the cross-ties.

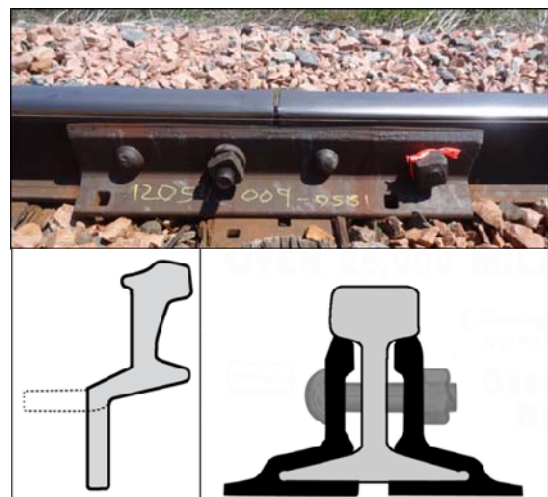


Figure 2. Unsymmetrical Joint Bar Designs (top), Bonzano (bottom left), and Continuous Angled or Angled (bottom right) Joint Bars

The Weber design originally had a fishplate that was even with the railhead (thus partially carrying the wheel), as well as a bottom plate to support the joint. The patent stated there would be little to no flex of the joint as a wheel passed over, thus reducing wear on both the track structure and on the wheel. Later designs did not have the outside fishplate even with the rail, but focused on using the integrated base plate to minimize joint motion.<sup>3</sup>

In the Bonzano joint bar (Figure 2), the outer part of the broad flange is bent down throughout the middle portion of its length into a hanging position for a length of about 4 inches at the lowest point and 8 inches at the bend. The presence of this very short but deep flange reduced the flexural action. Experimental data showed that bending stresses at the bend in the middle were about half of the joint bar with no bend.<sup>4</sup>

The shape of most unsymmetrical joint bar designs provided for a wider distribution of load, an apparently greater lateral resistance, and a greater value of the moment of inertia on both horizontal and vertical axes. In the consideration of the properties of these designs, it was commonly assumed that the neutral axis is horizontal under vertical loads and bending moments, and that it is vertical under lateral loads and bending moments. Therefore, the moments of inertia and the section moduli with respect to the vertical and horizontal axes were fully representative of the girder properties of the angled joint bar. However, this theory was proved otherwise experimentally by the AREA committee on track stresses.<sup>5</sup>

Various complex joint bar designs were used in the track during the first two decades of the 20<sup>th</sup> century. The railroads really wanted to standardize the design. As a result of the findings of the AREA committee on track stresses, the first standard joint bar design evolved.

### Standard Joint Bar Design

AREA committee on track stresses studied the mechanics of rail joints, both theoretically and experimentally. The most important finding was that, unlike symmetrical joint bar sections, which deflect vertically under vertical loads, the unsymmetrical sections such as angled joint bars are likely to deflect both vertically and laterally. Thus, the neutral axis is not a horizontal line, as is the case with symmetrical sections, but makes an angle with the horizontal line. This angle depends on the joint bar fit with the rail and tension in the bolts. Since the distance of the neutral axis at an angle is lower than the horizontal neutral axis, the resulting bending stresses are usually higher in angled joint bars. In the angled bars, the inclination of the neutral axis from the horizontal line may vary from 20 degrees to 55 degrees, and the ratio of the maximum stresses when the neutral axis is at angle to the calculated stress for neutral axis horizontal may vary up to 1.60. Figure 3 shows the inclination of the neutral axis for a typical angled joint bar.

This finding likely convinced the designers, manufacturers, and railroads that symmetrical (or nearly symmetrical) joint bars are more efficient and experience nearly the same levels of bending stresses as angled joint bars.

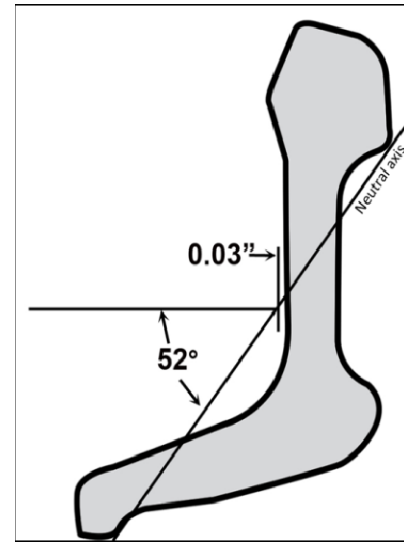


Figure 3. Neutral Axis of Angled Joint Bar under Vertical Load

The committee also recommended reducing the length of the bolts. There is about a 1-inch gap between the joint bar and rail webs at the neutral axis level. The length of the bolt used to fasten the joint can be reduced by reducing this gap. The relative movement of joint bar and rail creates bending in the bolt. Shortening the required bolt length is likely to reduce the bending stresses in bolts.

Based on the findings, the first AREA standard joint bar design was recommended in 1930s, which is basically the angled joint bar without a toe (Figure 4).

The joint bar makes a line contact on top and bottom and allows rail movement due to expansion and contraction. Railhead chipping was observed, which was most likely caused by the joint bar making contact with the railhead gage corner. Later, the contact was moved to the railhead-web fillet (head-free bar).

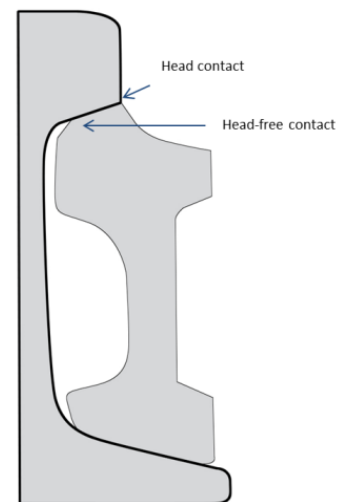


Figure 4. AREA 1930s Standard Joint Bar Design

Two notable features of the standard joint bar design are its symmetry and springiness. During the installation when the bolts are tightened, the joint bar settles in within the web. As a result, when the bolts are removed, the joint bar remains in the web and needs to be forced out. This feature, called springiness, is useful considering the fact that the bolts lose torque over time. However, springiness may not always be available because of rolling tolerances.

### Joint Bar Post Standardization Period

By the 1950s, most railroads had installed the standard joint bar design. A detailed survey of the railroads concluded that the standard design joint bar reduced the rate of failures. The causes of failures as suggested by the survey participants were:

- Fatigue cracks in decarburized metal at top or base of bar
- Insufficient anchorage
- Nicks in head fishing contact
- Overstressing above yield point
- Wear at top center
- Poor maintenance of rail joints
- Breaks sometimes caused by the effect of heat in building up rail ends
- Battered rail end
- Shallow depth responsible for light section failures
- Loose bolts; Swinging ties

It was noted by AREA committees that many of these issues pertain strictly to the initial installation and maintenance of the joints, and not to the design or specifications. It was further mentioned that high bolt tension was conducive to the development of high stresses around the bolt holes and bar failures of various kinds, particularly fatigue failures.

By the 1950s, various tests had indicated advantages of the 36-inch over the 24-inch length. In the tests, 36-inch joint bars lasted more than one and one half times longer than the 24-inch joint bars. Of particular interest was the record of the smoothness of the running surface of 36-inch versus 24-inch joint bars.<sup>6</sup>

### Recommendations for Future Work

The current standard joint bar design has served the railroads well. However, it was mainly intended for jointed rail territory to allow rail contraction and expansion. This feature is not desirable in continuous welded rail where the gap between rails may exceed 1 inch during cold weather. The Association of American Railroads' Strategic Research Initiatives Program intends to design a new joint bar profile that will have more resistance to rail thermal expansion and contraction.

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