TECHOLOGY DIGEST

Timely Technology Transfer — 02-024

Advanced Design Bainitic Steel Rail Crossing Diamonds under HAL Service

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Summary

Results from testing an advanced design crossing diamond, developed for improving dynamic performance and durability under heavy axle loads (HAL), showed that after 36 MGT of operation, the diamond had no major component failures and low running surface height loss rates. Improved dynamic performance was measured on the diamond, using load-measuring wheelsets.

The diamond design and construction was conducted under research and development project sponsorship by the Association of American Railroads. The prototype had several features intended to improve dynamic performance. These include:

- Running surface ramps: upward ramps toward flangeway corners optimized for 40-mph speed.
- Bainitic rail: J6 bainitic microstructure rail, previously proven successful under 39-kip wheel load traffic at the Federal Railroad Administration's Facility for Accelerated Service Test (FAST), Transportation Technology Center.
- Herringbone corner design: eliminates one rail from the crossing track running surface.
- Modified flangeway corner radii: smaller flangeway radii on inside corners.

Additional features for the test included milled seat plates and fastener type. Two fastener types were used for the frog bolts: conventional Grade 8 bolts and nuts with flat washers, and Grade 8 bolts with self centering washers and nuts.

Initial findings from the test include:

- Running surface ramps are effective. Ramps designed for 40 mph reduced maximum vertical loads by 40 percent to 1.5 × static (~60 kips) at 40 mph.
- The bainitic rail had relatively little deformation and wear under FAST operating conditions. J6 rail makes ramped running surfaces feasible.
- Ramped surface running rails had height loss rates similar to the 136-RE J6 rails tested in a conventional diamond. The ramps did not materially affect height loss rates.
- At 1,750 ft-lbs of torque, six of 48 frog body bolts came loose in the first 30 MGT. No performance differences between conventional and self-centering nuts were noted.
- Milled seats were effective at reducing plate fastener failures: there were no fastener failures during the FAST test.
- The herringbone corner design looks promising: the herringbone arrangement of rails at the frog common corners allows elimination of one rail from the branchline running surface. No early failures of running rails or filler iron were noted.
- The reduced inside corner radius contributed to development of sharp corners from wheel back of flange wear and metal flow.

Suggested Distribution:

- ☐ Maintenance of Way
- ☐ Planning & Analysis
- ☐ Track Maintenance
- ☐ Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads

INTRODUCTION

An advanced design crossing diamond was developed to improve the dynamic performance and durability under heavy axle load (HAL) traffic. Crossing diamonds have high impact loads that cause damage to the flangeway gap corners. One of the reasons for the high impact loads on a high angle crossing diamond is the wheel is unsupported as it crosses the flangeway gap. As the wheel rolls across a level running surface and into the gap, it falls and bluntly strikes the gap corner on the opposite side. The resulting impact loads may be as high as 2 to 4 times static wheel load. In a previous test performed by Transportation Technology Center, Inc. (TTCI), running surface ramps designed to reduce impact loads for HAL freight service between 40 and 80 mph were tested. That test showed a 1:64 ramped surface had a maximum reduction in impact loads at 50 mph of 38 percent.[1]

TEST AND RESULTS

In January 2002, the crossing diamond was installed in Section 40 at the Facility for Accelerated Service Testing (FAST) located at the Transportation Technology Center (TTC), Pueblo, Colorado. The diamond was placed on a foundation consisting of prepared granular subgrade, an 8-inch hot mix asphalt (HMA) pavement, and a 12-inch granite ballast layer. The 12-foot-wide by 50-foot-long HMA underlayment was constructed in 1999. Thus, the diamond's foundation has settled and stabilized with over 150 MGT of HAL traffic prior to the test. The diamond was installed and surfaced with a slight crown in the track profile. After 2 MGT of initial settlement, the diamond was surfaced to a level profile.

Over the mainline route, 39-kip wheel load traffic was operated at 40 mph for 27.7 MGT. In April, dynamic wheel loads were measured operating over the diamond at speeds of 30, 40, and 42 mph. The crossing was then rotated so that HAL traffic ran over the branchline route of the diamond. Another 8.3 MGT was accumulated before the annual summer shutdown of FAST.

Running Surface Ramp Dynamic Performance

The prototype crossing diamond was constructed with running surface ramps designed to reduce impact loads at 40 to 50 mph. The ramps are 1/8 inch in 6 inches. The prototype also has a "herringbone corner configuration" eliminating one of the rails from the branchline running surface. This eliminates one of the gaps wheels must traverse on the branchline.

The running surface ramps reduce impact loads by helping the car wheels over the flangeway gaps. The ramps counteract gravity; keeping the wheels from falling in the gaps by generating upward velocity in the components of traversing cars.[1] The loads were recorded by instrumented wheelsets for 30- to 45-mph runs. The maximum vertical wheel load was recorded at 30 mph of approximately 70 kips. The maximum load at the design speed of 40 mph was approximately 58 kips. This is approximately 1.5 times static wheel load. A comparison of previous FAST tests and the prototype ramped diamond crossing is shown in Figure 1. The previous FAST three-rail, 62-degree crossing diamond had a maximum vertical wheel load 2.3 times static wheel load at 40 mph. The running surface ramps are effective at lowering maximum vertical impact loads at the design speed.

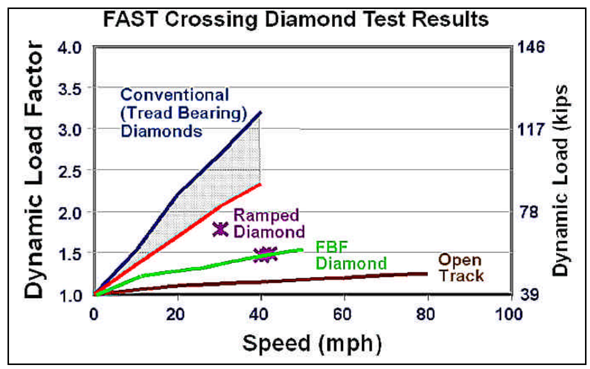

Figure 1. Comparison of Maximum Dynamic Loads versus Diamond Design

Running Surface Height Loss

Figure 2 shows a comparison of previous running surface height loss with the bainitic three-rail diamond and the ramped prototype crossing diamond at FAST. The graph shows the wear on the common corners of the crossing diamond. The prototype crossing diamond has similar wear to the previous crossing diamond in the first 30 MGT of traffic. The prototype diamond was rotated for branchline traffic at 27 MGT. The increase in the rate of wear after the diamond was turned is a result of the material being pushed and flowing in a different direction. The effect of cross traffic on wear rate was also noted in the bainitic crossing diamond revenue service tests.[2]

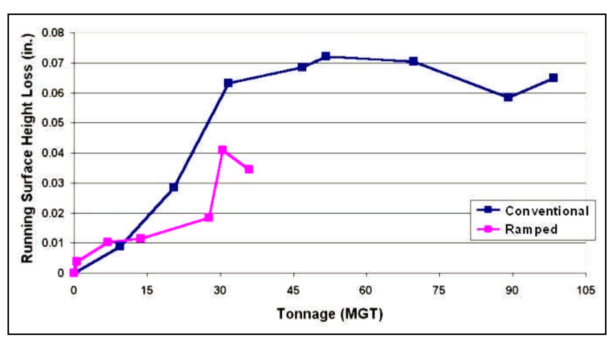

Figure 2. Comparison of FAST Ramped and Flat Running Surface Bainitic Rail Diamond Performance

Frog Bolt Test

Two fastener types were used for the frog bolts: 1) conventional Grade 8 bolts and nuts with flat washers and, 2) Grade 8 bolts with self-centering washers and nuts. The bolts were monitored for movement and re-torqued, as necessary. The initial torque value used was 1,750 ft-lbs. The supplier torqued the bolts to this value on the diamond subassemblies before they were shipped to TTC. TTCI assembled the diamond and torqued or re-torqued all 48 test bolts to this value. Each type of fastener was used in two of the frogs, as Figure 3 shows.

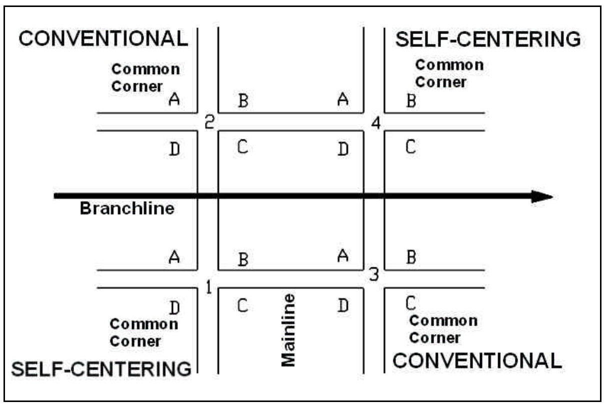

Figure 3. Crossing Diamond Test Fastener Layout at FAST

One each of the self-centering bolts loosened completely at 9, 20, and 27 MGT. Three of the conventional bolts loosened completely at 27 MGT. When the crossing diamond was rotated to run on the branchline, the bolts were torqued to 2,200 ft-lbs. In the first 8.3 MGT of traffic, none of the bolts had loosened (Table 1).

Conclusions have not been drawn with regard to the fastener type test. Additional tonnage is needed at the higher bolt torque value. The data does suggest that 1,750 ft-lbs is inadequate to keep bolts tight on a new crossing diamond subjected to HAL traffic.

Table 1. Location and Number of Loose Bolts

Location	Number of Loose Bolts	
Self-centering	**1,750 ft-lbs**	**2,200 ft-lbs**
Corner 1	1	0*
Corner 4	2	0*
Conventional	**1,750 ft-lbs**	**2,200 ft-lbs**
Corner 2	0	0*
Corner 3	3	0*

*Diamond had 8.3 MGT of traffic since increasing the torque.

Herringbone Corner Design

The prototype crossing diamond has a herringbone corner configuration eliminating one of the rails from the branchline running surface. Figure 4 shows the herringbone corner as tested. Eliminating the mainline easer rail from the branch track running surface helps to minimize the impacts due to the gaps the wheel must traverse. This corner configuration also weakens the diamond in bending by eliminating the running rail to easer rail filler iron that would normally span the branchline flangeway. The flangeway filler is the sole component spanning the branchline flangeway gaps. As usual, there are no components spanning the mainline flangeway.

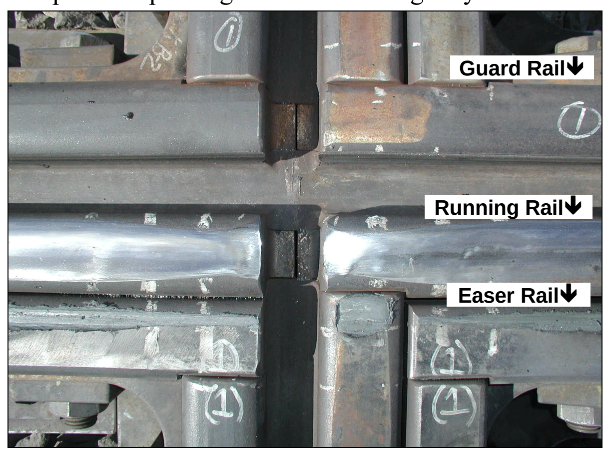

Figure 4. Plan View of Herringbone Corner as Tested at FAST

This design is weaker in beam strength and longitudinal strength for the mainline route. Problems that may arise from the arrangement of frog rails include fatigue cracking of the flangeway filler bar and /or the three mainline rails (running rail, guard rail, and easer rail) that make up the mainline side of the frog. Also, the branchline running railhead is cantilevered over the mainline flangeway filler bar. Foundation/support conditions can greatly affect the dynamic load environment and frog deflection conditions. TTCI will continue monitoring the performance of the corner components to determine the long-term effects of this design.

The long-term performance of the herringbone corner cannot be determined from 36 MGT of HAL service. However, the following preliminary conclusions can be drawn.

- The elimination of one rail from the branchline route does improve the performance of the running surface.
- No early cracking of rails or filler iron were noted. This corner configuration can survive HAL traffic provided the diamond has good surface, good support, and tight bolts.

FUTURE WORK

The crossing diamond has provided improved dynamic performance and required reduced maintenance under HAL service conditions at FAST. After some additional branchline traffic, the diamond will be installed on the Union Pacific Railroad to determine its performance under revenue service conditions. Differences between revenue service and conditions at FAST include train speeds, wheel profiles, and traffic.

Acknowledgements

Cleveland Track Material, Inc. made the crossing diamond from J6 rail supplied by TTCI. Engineers Karl Axthelm, Eddie Aldridge, and Jim Remington were essential in developing TTCI's design ideas into an actual prototype.

References

1. Singh, S. P., D. Guillen, and D. Davis. "Proof Tests of Crossing Diamond Surface Ramps in Heavy-Axle-Load Service," *Technology Digest* TD99-024, Transportation Technology Center, Inc., Pueblo, Colorado; July 1999.
2. Davis, D.; D. Guillen, J. Robeda and C. Sasaoka. "Field Performance of Bainitic Steel Rail Crossing Diamonds," *Technology Digest* TD01-015, Transportation Technology Center, Inc.; Pueblo, Colorado; November 2001.

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