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## Performance of an Advanced Design Diamond Crossing in Revenue Service

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### Summary

Revenue service testing of an advanced design crossing diamond has demonstrated the effectiveness of innovative design features and provided relative comparisons of running surface wear rates under two load environments.

A 90-degree diamond crossing was made with bainitic steel rail to a modified three-rail design. The diamond crossing was made for heavy axle load testing at the Federal Railroad Administration's Transportation Technology Center (TTC). After a brief proof test at TTC's Facility for Accelerated Service Testing, the diamond was installed in a mixed freight revenue service line.

Findings from this test:

- Crossing diamond performance and life cycle costs can be improved over conventional designs.
- The ramped corners performed well. Dynamic forces (as measured by load measuring wheelsets), ride quality (as "measured" by FAST train crews), and running surface height loss were all improved on this diamond crossing.
  - The ramps are durable. The mainline ramps are still in existence after 125 MGT of traffic. The branchline ramps have been "cut" by false flanges from mainline traffic.
  - Running surface height loss rates are one-third lower for ramped than for flat running surface diamonds in comparable service.
- Herringbone corners have proven to be durable. The new arrangement of frog rails has proven to be durable. The diamond has good alignment and few broken parts.
- The J6, medium carbon, bainitic rail has performed well in this application. Some rolling contact fatigue has been observed at the mainline rail gage corner. This is due, at least in part, to the sharp corners made for the ramped running surfaces.
- Milled plates have worked well. The 1 1/4-inch thick plates with 1/4-inch milled seats have performed well. To date, there is no plate cracking. The diamond has remained in the plate seats.
- A comparison of fastener performance shows that conventional bolts, nuts, and flat washers and self-centering bolts, nuts, and washers work well with higher torque applied. At 1,700 ft-lbs, both types of fasteners failed at about twice the rate seen at 2,300 ft-lbs.
- Revenue service operations generated higher running surface area loss rates than FAST. This may be due to higher dynamic forces (i.e., higher train speeds) and higher contact stresses (i.e., more hollow tread profile wheels).



## INTRODUCTION

A 90-degree diamond crossing was built as a test bed for evaluating advanced design concepts, frog materials and maintenance practices for heavy axle load service. Building on the lessons learned in revenue service by the AAR Special Track Work Technical Advisory Group and at FAST, an “advanced design” prototype was built. It incorporated a few proven best practices designs and some unproven design concepts.

Features of the diamond crossing include:

- Ramped running surface corners — made to Association of American Railroad design to minimize vertical forces for 40 mph traffic.<sup>1,2,3</sup> The ramps were 6 inches long with a 1:48 slope upward toward the flangeways. Figure 1 shows the ramps after 100 MGT of service
- Herringbone corners – arrangement of the supporting rails was changed at the frogs to eliminate the easer rails from the branchline running surface. This should make the crossing route smoother. The crossing base plate was made thicker to compensate for the loss of mainline bending strength. Figure 2 shows a conventional diamond frog and the Herringbone arrangement. Note that the branchline running rail butts against the mainline running rail, removing the mainline easer rail from the branchline running surface.
- Bainitic rail – rails in the diamond were medium carbon bainitic. The rail has higher impact toughness and comparable rolling contact fatigue resistance than conventional pearlitic rail.<sup>4,5</sup>
- Milled plates – base plate has milled seats to assist in holding the diamond crossing in alignment. Typical designs rely on welded stops to hold the diamond in alignment. The stop welds often fail, cracking the plate or the stop. Figure 3 shows the diamond’s milled seat plate work.
- Self-centering bolts – Union Pacific standard self-centering bolts and washers were installed on half of the diamond. These components are designed to minimize bolt breakage due to shear or bending forces. Figure 4 shows self-centering and conventional bolts.



Figure 1. Ramped Running Surfaces after 100 MGT of Traffic



Figure 2. Conventional and Herringbone Rail Arrangements at Diamond Frog



Figure 3. Milled Rail Seat Base Plate (note ¼ inch milled seat at end of easer rail)



Figure 4. Self-Centering and Conventional Fasteners

**Test Environments**

Figure 5 shows the diamond crossing in test at FAST (in Pueblo, CO) and at Ontario, CA.

Table 1 compares and contrasts the test conditions for the ramped diamond crossing. FAST has more closely controlled load variables. In essence, operation at FAST is close to the optimal for controlling dynamic loads and reducing stresses in the track structure. Thus, the effects of the higher static wheel loads on track have been largely mitigated.



**Figure 5. Diamond Crossing Test Locations: (L) FAST & (R) Ontario, CA**

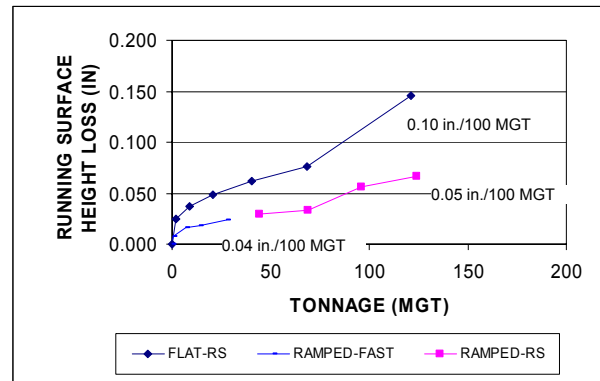
**Table 1. Test Conditions**

Test Variable	FAST	Revenue Service
Wheel Load	39 kips	Distribution from 8 to 39 kips
Train Speeds	40 mph	10 to 60 mph
Traffic Rate	5 MGT/ week	5 MGT/ month
Operations	Large scale fleetling (e.g., 120 trains in same direction on 4-min. headways)	Large scale fleetling is uncommon. Train spacing varies with operations.
Wheel Profiles	FAST conformal - Max. hollowing: 1 mm	Revenue Service Worn - Max. hollowing: 6 mm
Dynamic load due to wheel defects (on open track)	Max: 60 kips	Max: 140 kips (removal criterion: 90 kips)
Climate	High plains: dry with wide temperature range	Coastal plains: dry with warm temperatures

**Revenue Service Performance and Evaluation of Design Features**

Measurements of running surface height loss were made on the diamond when in service at FAST and at Ontario, CA. Height loss encompasses both metal flow and wear of the running surface. At high impact locations, such as flangeway gaps, metal flow can be the dominant factor in running surface height loss. In conventional track, wear and rolling contact fatigue are more important. Figure 6 shows average running surface height loss for the mainline route of bainitic rail diamonds tested. Note that the running surface height loss rate is lower for the ramped diamond than for conventional flat (i.e., no ramps) running surface bainitic rail diamonds. The plot shows average height loss rates of 0.10 in./100 MGT for three flat running surface bainitic rail diamonds in revenue service, 0.05 in./100 MGT for the ramped diamond in revenue service and 0.04 in./100 MGT for the same ramped diamond in FAST. The gap in the ramped diamond data is from the period when FAST operations occurred on the branchline route and when the diamond was relocated to revenue service. Also note that the average

running surface height loss rate did not decrease in revenue service, despite lower static wheel loads. It may have increased slightly as the rates measured are about 20 percent higher. In addition, the wear patterns at FAST and revenue service differ. Figure 7 shows the same corner of the diamond after 30 MGT in FAST and after 90 additional MGT in revenue service. The FAST wear band is narrower, with few wheels bearing on the easer rail. The revenue service wear band extends across the entire running rail and has a significant groove worn in the easer rail. Thus, while the running surface height loss rates are similar, the total rail cross sectional area change is higher in revenue service.

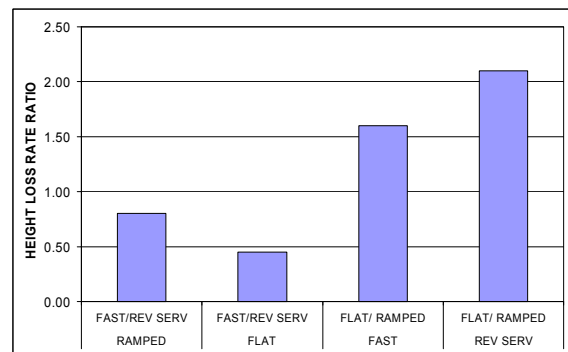


**Figure 6. Test Diamond Crossing Running Surface Height Loss vs. Tonnage**



**Figure 7. Comparison of Ramped Running Surface Wear Patterns at FAST and in Revenue Service**

Analysis of the effects of load environment and running surface longitudinal profile was conducted using the running surface height loss data. Figure 8 shows a comparison of running surface height loss rate for ramped and flat diamonds at FAST and in revenue service.



**Figure 8. Effects of Load Environment and Running Surface Design on Diamond Performance**

Comparison of flat and ramped running surfaces at FAST suggests that the flat surfaces “wear” at flangeway corners about 50 percent more per MGT. Revenue service shows the same trends in a more tenuous comparison of performance at different sites. The ramped running surface should reduce dynamic loading for trains operating at track speed, and thus reduce running surface flow.

The data also suggests that the FAST dynamic load environment, despite the higher static wheel loads, is no more severe than revenue service (see the FAST/UP comparisons). The same ramped diamond crossing has similar running surface height loss rates in revenue service. The comparison of flat running surface diamonds has more uncontrolled variables, but shows the same trend. Potential explanations for the higher height loss rates despite lower average wheel loads in revenue service include:

- Ramp wear. As the ramps wear their effectiveness will diminish.
- Variations in train speeds. The running surface ramps were designed for 40 mph operations and will perform best for trains near this speed.
- Wheel profiles. FAST has profiles that are conformal to the rails, with little tread hollowing. Revenue service has a wide range of wheel profiles. These wheels produce adverse steering and higher contact stresses.
- Vehicle and truck maintenance. Car performance monitoring allows FAST to control dynamic loads more closely than can be done in revenue service. As a result, vehicle conditions that can cause high dynamic loads are remedied sooner. The result is a lower vehicle caused dynamic load environment.

## TEST RESULTS

- Dynamic forces (as measured by load measuring wheelsets), ride quality, (as observed by FAST train crews) and running surface height loss were all improved on this diamond crossing.
  - The mainline ramps are still in existence after 125 MGT of traffic. The branchline ramps have been “cut” by false flanges from mainline traffic.
  - Running surface height loss rates are lower for ramped than for flat running surface diamonds in comparable service.
- The new arrangement of frog rails has proven to be durable. The diamond has good alignment and few broken parts.
- Some rolling contact fatigue has been observed at the mainline rail gage corner. This is due, at least in part, to the sharp corners made for the ramped running surfaces.

- The 1 1/4-inch thick plates with 1/4-inch milled seats have performed well. To date, there is no plate cracking. The diamond has remained in the plate seats.
- A comparison of fastener performance shows that conventional bolts, nuts, and flat washers and self-centering bolts, nuts, and washers work well with higher torque applied. At 1,700 ft-lbs, fasteners failed at about twice the rate seen at 2,300 ft-lbs.
- Revenue service operations generated higher running surface area loss rates than FAST. This may be due to higher dynamic forces (i.e., higher train speeds) and higher contact stresses (i.e., more hollow tread profile wheels).

## FUTURE WORK

The advanced design diamond tested at FAST and in revenue service offered several features that improved performance. One is the more durable bainitic steel running rails. While J6 has proven to provide performance benefits for high angle frogs, it may not have such relative advantages as a rail steel. Thus, TTCI will evaluate other improved toughness steels for this application. The latest generation of high-hardness pearlitic rail steels will be evaluated as well as variants of austenitic manganese steel.

## Acknowledgements

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