U.S. Department
of Transportation
Federal Railroad
Administration

RESEARCH RESULTS
FRA OFFICE OF RAILROAD POLICY & DEVELOPMENT

RR 16-17 | **June** 2016

PROTOTYPE NEXT GENERATION FROG FOUNDATION – PRELIMINARY EVALUATION

SUMMARY

A frog foundation research project, jointly funded by the Federal Railroad Administration and Association of American Railroads, and conducted at the Facility for Accelerated Service Testing (FAST), tested a flexible frog crossing diamond prototype and it performed as intended. The tests have resulted in reduced wheel impact loads, reduced settlement, and no major structural component failure after 21.62 million gross tons (MGT) of 315-kip gross rail load (GRL) traffic operated at 40 mph.

Transportation Technology Center, Inc. (TTCI) in Pueblo, Colorado, performed modeling and previous testing under FRA Task Order 265. As a result, a prototype crossing diamond has been designed and fabricated that improves dynamic performance by introducing flexibility at the flangeway gaps as a primary feature.

This phase of the project quantifies the improvements in the dynamic environment which were predicted to occur due to flangeway gap flexibility, as well as the presence of stiffness/damping control pads between the castings, the plate work, and under the crossties.

The dynamic environment is evaluated by measuring the vertical track stiffness, track settlement, changes in the effective flangeway gaps, running surface wear/degradation, and dynamic wheel-impact loads.

The static vertical stiffness tests indicate similar results as seen in previous crossing diamonds that were tested at FAST.

A comparison of settlement during a similar tonnage period and maintenance conditions indicate half as much settlement on the prototype crossing diamond versus a previously tested diamond of the same basic casting elements (the “cast diamond”).

Early test results indicate a 17–28 percent reduction in impact loads over the prototype (94 kips at 40 mph) as compared to the cast diamond (120 kips at 40 mph).

While the prototype diamond has been in service, one structural component, a bolt, has broken. Other nonstructural and welded components, which were designed to guide the diamond on the milled plates, broke and were rewelded. The original rubber pad between the bottom of the castings and the plate work disintegrated after one night of train operation. A new pad was installed and has been performing well in service for 18.56 MGT.

Figure 1. IWS consist over the prototype flexible frog diamond

BACKGROUND

In previous phases of the project, the effects of track stiffness and damping were studied and it was discovered that these parameters can have significant impacts on dynamic forces. During these studies, it was also determined that frog configuration was important.

Conventional wisdom suggests that a solid or rigid one-piece frog is preferred because it is easy to maintain. However, testing and subsequent modeling demonstrated that a flexible frog (i.e., a two-piece frog split in the flangeway) produced significantly lower maximum vertical forces with the same heavy axle load traffic. When developing a crossing diamond prototype with flexible frogs and optimal foundation properties became feasible, the prototype presented in this report was built.

OBJECTIVES

In this phase of the project, the team developed, built, and tested a prototype frog and foundation. The following tasks were performed during this phase:

- Identified existing frog designs that might be modified to produce the desired characteristics of a more flexible frog
- Constructed a prototype that would allow evaluation of various foundation materials and the flexible frog concept
- Provided a preliminary evaluation of the prototype under 315-kip Gross Rail Load (GRL) railcar traffic

METHODS

The prototype was developed from the straight rail reversible casting design (an existing design), which allowed the team to use existing casting patterns while saving resources and development time. Also, the prototype was configured to accommodate a range of rail seat and under-tie bearing pads. The first set of rail seat pads was intended to provide near optimal track stiffness and damping.

Once the prototype was completed, it was installed in the FAST's High Tonnage Loop. Dynamic loading was applied using 315-kip GRL vehicles operated at 40 mph. Figure 2 shows the prototype diamond after it was installed in the testbed.

The following measurements were made in the field:

- Track stiffness
- Track settlement
- Flangeway gap widths
- Wheel/rail dynamic loads
- Identification and count of broken components

Figure 2. Prototype Frog Foundation Crossing Diamond

RESULTS

Figure 3 displays the vertical track stiffness measurements that were taken over the prototype crossing diamond and its approaches. The results were comparable with previous crossing diamonds tested at FAST, where the stiffness at the center of the crossing is about 200,000 lb/in.

Figure 3. Vertical Track Stiffness

The top of rail elevation measured over the diamond is shown in Figure 4.

The early results indicate that the prototype diamond has better settlement performance (less settlement at the diamond center) than a cast diamond that was previously tested at the same location. After the first raise and tamping maintenance performed on the cast diamond, settlement was 2.14 inches during the 1.07 MGT measurement interval, which was approximately a rate of 2.0 inches per MGT. By comparison, the prototype diamond settled at a rate of 0.8 inch/MGT during the 1.3 MGT measurement interval (following its first raise and tamping maintenance where it settled 1.06 inch).

Figure 5 shows the settlement rate at the center of the diamond, where the rate has diminished to about 0.9 inch per 100 MGT over the last 11.6 MGT measurement cycle.

The effective flangeway gap was measured with the instrument in Figure 6. The plastic, 8-inch chord reproduction of a 36-inch wheel is used to trace the rolling path over the flangeway gap. A section of carbon paper fastened to the clips captures the wheel's running surface contact and indicates where the last and first wheel contacts were on each side of the flangeway gap.

Figure 4. Top of Rail Elevation

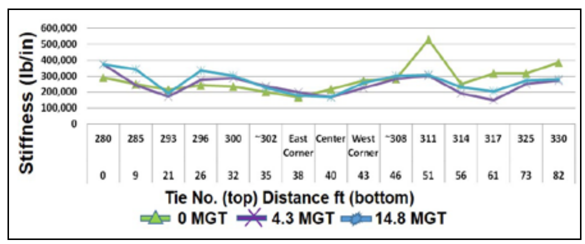

Figure 5. Settlement rate at the center of the diamond during three measurement cycles

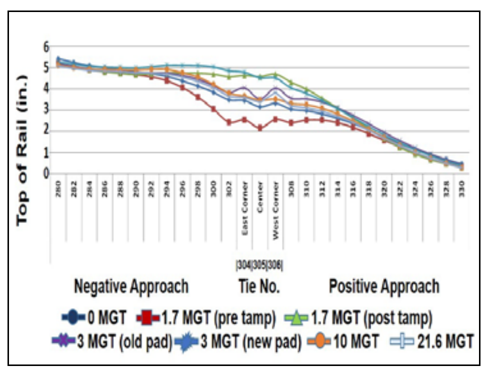

Figure 6. Wheel flangeway gap measurement instrument developed by TTCI

Figure 7 shows the effective flangeway gaps measured on the prototype diamond. The maximum and minimum gaps, measured over 14 MGT, were 2.83 inches and 2.25 inches respectively. The largest gap size variation for the four corners within each measurement cycle was 0.25 inch. The variations between measurement cycles are likely due to running surface batter and changes in rail longitudinal stress.

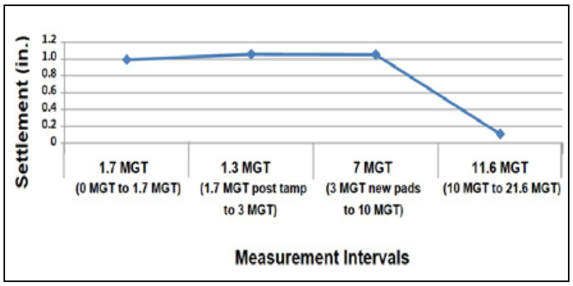

Figure 7. Flangeway gaps measured on the prototype diamond

Instrumented wheelsets were used to measure the vertical forces over the diamond. The early results indicate a 17–28 percent reduction in impact loads over the prototype (94 kips at 40 mph) as compared to the cast diamond (120 kips at 40 mph). Figure 8 shows the maximum vertical loads measured on the two types of diamonds and on open track.

Figure 8. Measured Maximum Vertical Loads

ACKNOWLEDGEMENTS

Principal Investigators from TTCI are Rafael Jimenez, David Davis, and Joseph LoPresti. Testing support was also provided by Dennis Wright and Gary Click from voestalpine Nortrak.

CONTACT

Luis Maal
Program Manager
Federal Railroad Administration
Office of Research and Development
55500 DOT Road
Pueblo, CO 81001
(719) 584-0551
luis.maal@dot.gov

Gary Carr
Chief – Track Division
Federal Railroad Administration
Office of Research and Development
1120 Vermont Avenue NW - Mail Stop 20
Washington, DC 20590
(202) 493-6354
gary.carr@dot.gov

KEYWORDS

Frog Foundations

Frog Design

Notice and Disclaimer: This document is disseminated under the sponsorship of the United States Department of Transportation in the interest of information exchange. Any opinions, findings and conclusions, or recommendations expressed in this material do not necessarily reflect the views or policies of the United States Government, nor does mention of trade names, commercial products, or organizations imply endorsement by the United States Government. The United States Government assumes no liability for the content or use of the material contained in this document.