TTCI TECHNOLOGY DIGEST

JULY 2020 TD20-016

The research described was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Key Findings:

- For conventional crossing diamonds, good support conditions (no excessive displacement; generally <0.5 inch) appear to play the greatest role in ensuring that impacts in conventional diamonds are minimized.
- Based on current data, either two or three layers of pads in conventional diamonds with good support (<0.5 inch displacement) appear to reduce and damp impacts compared to no pads with good support conditions. These locations will continue to be monitored.
- In poorly supported situations (>0.5 inch displacement), two layers of pads damp impacts into the diamond, and appear to provide some benefit.
- TTCI will continue to monitor settlement at two diamond locations: 1) a double flange-bearing diamond with similar pad configurations on each diamond, but uses different pad vendors; 2) a double conventional diamond. Both locations have three layers of pads, but one diamond has under rail pads while the other diamond uses steel shims. After 18 months, no meaningful difference in settlement has been observed.

Interim Report: Crossing Diamond Foundations

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Transportation Technology Center, Inc (TTCI) is currently monitoring four diamonds from three Class I railroads with different diamond configurations to investigate optimal foundation designs. The results show that support conditions play a significant role and pads appear to be beneficial even in poor support conditions.

Crossing diamonds are a significant maintenance challenge for North American railroads because the wheels must cross flangeway gaps, resulting in impacts that can accelerate crossing diamond foundation and component deterioration. Some railroads have made efforts to avoid this with One-Way Low-Speed (OWLS) crossings, but this is not desirable for the crossing of two high tonnage routes. Flange bearing crossing diamonds are another option but can be less desirable than conventional diamonds due to their significant initial cost. For this reason, engineered polymeric/polyurethane pads are beginning to be included within new crossing diamonds (conventional and flange bearing) to reduce impacts and extend diamond life.

In a previous Federal Railroad Administration (FRA) study to develop a new generation of conventional crossing diamonds, TTCI tested new diamond designs at the Facility for Accelerated Service Testing (FAST), Pueblo, CO, and showed that one-layer of engineered pads potentially could reduce wheel impacts and extend diamond life.[1] A second study at FAST found that under-tie pads (UTPs) can reduce stiffness variation between the diamond and surrounding track.[2] A third study in revenue service showed that pads can reduce impacts at turnouts.[3] The Association for American Railroads (AAR) Strategic Research Initiative (SRI) program has expanded on these studies by testing multiple diamonds with engineered pads in revenue service.

The results to date included in this *Technology Digest* should be considered preliminary as no definitive conclusions can be made at this time. Future work will include monitoring of these diamonds and testing new diamonds to get a wider range of situations.

DIAMOND DETAILS

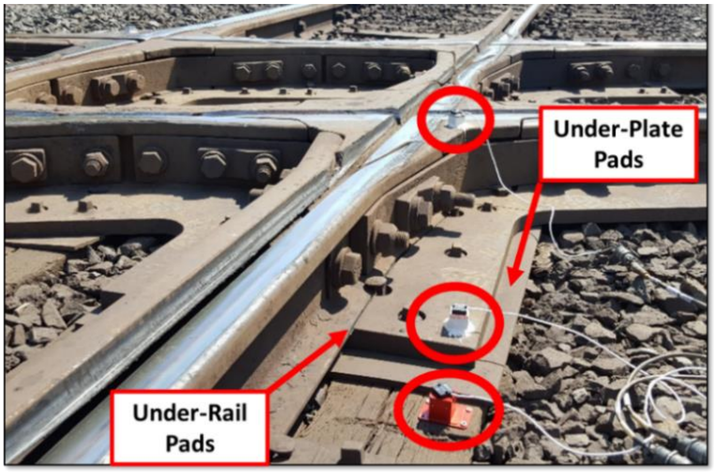
Engineered pads are being installed at multiple locations within conventional crossing diamonds. This includes under-rail pads, under-plate pads, and under-tie pads (UTPs). The under rail and under plate pads are higher up in the diamond and should reduce diamond stiffness, impacts, and provide daming to the platework. The UTPs are more focused on reducing the stiffness of the entire diamond and reducing ballast breakdown. Details of the four crossing diamonds are listed:

- **Railroad A conventional diamond:** A conventional diamond crossing with about 80 annual MGT crossing track in Idaho with about 40 annual MGT. The original design had UTPs and under-plate pads (two-layers). The new design installed in April 2019 had under-rail pads, as well (three layers).
- **Railroad B conventional diamonds:** Two conventional diamonds with about 100 annual MGT on double mainline track crossing track in Manitoba, Canada with about 10 annual MGT. The original design had no pads.
- **Railroad C conventional diamonds:** Two conventional diamonds with an unknown annual MGT due to multiple turnouts on double mainline track crossing track in midwestern United States with about 1 annual MGT. Both diamonds have UTPs and under-plate pads, but one diamond has under-rail pads and the other has steel shims under the rail.
- **Railroad C flange-bearing diamond:** Two flange-bearing diamonds with an unknown annual MGT due to multiple turnouts on double mainline track crossing track in the midwestern United States with unknown MGT. Both diamonds have UTPs and under-plate pads, but each diamond has a different pad supplier.

MEASUREMENTS

The project study was created to determine whether two or three pad layers were preferable for extending diamond life. Railroad A has historically used two pads (UTPs and plate pads), but questions whether a third pad under the rail would help or overdamp and soften the diamond. Accelerometers were installed at three locations: casting, plate, and tie — and results of the two-layers and three-layers were compared. The Railroad B diamond was added because its location allowed measurements in thawed and frozen subgrade conditions.

Accelerometers were chosen because they can measure the impacts and vibrations occurring at different levels of the crossing diamond. For a well-supported diamond (defined as diamonds with displacements less than 0.5 inch) that has pads, the impacts should not exceed 200g and the peak acceleration from impact should decrease as the impact travels downward into the diamond. However, accelerometers should only be used to give insight into the problem because of the complexity of impacts and vibration and because a lower acceleration does not always indicate better performance. Figure 1 shows typical accelerometer placement on a conventional crossing diamond.



(a)

(b)

Figure 1. Photographs showing (a) accelerometer locations (red circles) along with under-rail and under-plate pads and (b) close-up of under-plate pads

The Railroad C diamonds were originally part of a separate study that focused on diamond settlement — these diamonds have been monitored using top-of-rail (TOR) elevations. In the future, the Railroad C conventional diamond will be monitored with accelerometers as well.

RESULTS: ACCELERATIONS

The results of the diamond conditions and acceleration results are presented in this section. For the diamond condition, only aspects that are relevant to the acceleration results are included.

Diamond Condition

The Railroad A conventional diamond was monitored on August 2, 2018 and July 2, 2019. The first inspection had a diamond with two layers of pads near the end of its life cycle. The second inspection had a new diamond with three layers of pads and was only three months post-installation.

On the first monitoring trip with two pad layers, two corners of the diamond were instrumented. On one corner, the diamond appeared in good condition and was well-supported (<0.5 inch displacement). On the opposing corner, however, the under-plate pads had moved and the diamond had settled, so the pads were not in contact with the base plate. During train passage, there was significant movement (>0.5 inch displacement) and vibration. Therefore, the first corner is labeled well-supported and the second corner is labeled poorly supported.

On the second monitoring trip with three pad layers, the same two corners were monitored. On both corners, the diamond was well-supported and displayed minimal movement. Therefore, the three-pad Railroad A diamond has only well-supported conditions at this current time.

The Railroad B conventional diamonds with no pads were monitored on October 1, 2018 and March 5, 2019. The intention of the two trips were to get a thawed trip (October) and frozen trip (March). As anticipated, the frozen trip had much less displacement than the thawed because of the frozen subgrade and gave a zero-pad scenario comparing good and poor support conditions.

Acceleration Results

This section summarizes the results of the accelerometer measurements examining how different pad configurations and frozen conditions affect performance. Peak accelerations can give important insight into diamond performance, but the results should always be presented with context and supplemented with other factors such as diamond displacement, installation date, and maintenance needs. Figure 2 presents the results of the accelerometers at the Railroad A and Railroad B diamonds.

The results show that poor support significantly increases the impact acceleration. This is not surprising as poor support results in higher deflections allowing for more impacts between components. This increased movement and more severe impacts will naturally deteriorate crossing components and reduce life. A second observation is that for the padded configurations (both good and poor support), the casting experienced the greatest acceleration. This indicates there is some damping within the system and this will likely benefit the components and foundation. A third observation is that the two-pad configuration has lower accelerations than the three-pad configuration. This is a result of interest but cannot support any hard conclusions at this time because the difference between 80g impacts and 120g impacts may be the result of multiple other factors besides pad configurations.

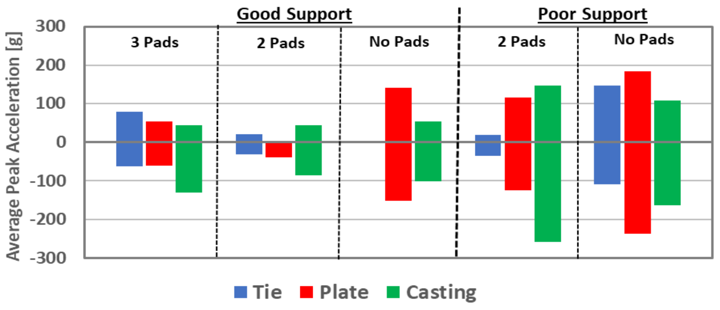


Figure 2. Accelerations results from various pad locations and support conditions

In summary, the results suggest that support conditions play the greatest role in diamond performance in terms of acceleration. Pads do appear to help, whether supported or not supported, because the pads damp the impact force as it moves downward into the diamond. Both two- and three-pad configurations perform well when well-supported.

RESULTS: TOP-OF-RAIL

In addition to the Railroad A and Railroad B conventional diamonds, the settlement results from the Railroad C diamonds also are included in Figure 3. While the settlement magnitudes are presented together, the lack of knowledge of MGT does not allow for comparisons between the flange bearing and conventional diamonds.

Results show that the greatest settlement in the flange-bearing diamond appears to occur away from the diamond near a number of joints. The deflection at this location was noticeable during train passage. However, the condition of the flange bearing diamond appeared good. The conventional diamond did appear to have greater settlement than the surrounding track, which is not surprising because of the impacts even with the under-plate pads and UTPs. No conclusions can be made comparing the two pads for the flange bearing diamond and the rail pads and steel shims for the conventional diamond. Overall, both the flange bearing and conventional diamonds appear to be performing well, but it is still too early to determine whether either pad type at the flange bearing or steel versus pad under-rail support is superior.

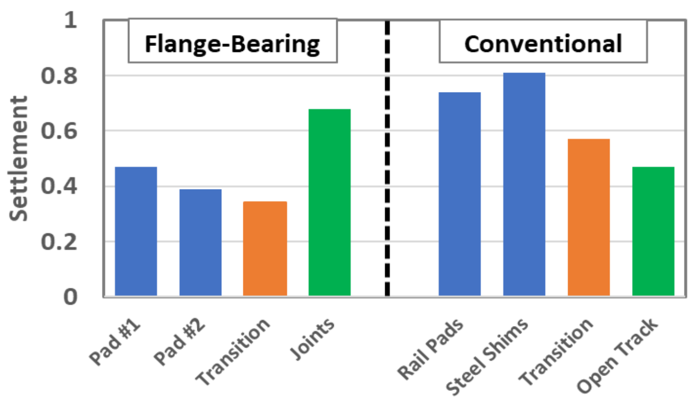


Figure 3. Settlement results from different locations at two different diamonds (the two diamonds cannot be directly compared)

FUTURE WORK

This report summarizes current observations to date, but additional measurements are planned to expand and build upon these results. Future efforts include:

- Continued monitoring of the Railroad A three-pad conventional diamond. As additional tonnage is accumulated, the comparison between the three-pad and two-pad configurations should become more distinct.
- The Railroad C conventional diamond will be monitored with accelerometers during future trips in a similar manner to the Railroad A and Railroad B diamonds. TOR measurements will continue on both Railroad C diamonds.
- New conventional diamonds are being investigated as additional data points because of the potential variability between sites. For example, each diamond has numerous individual features that influence the acceleration values; thus multiple diamonds with similar pad configurations will help provide insight into how much variability exists even between two diamonds with identical pad configurations.

References

1. Davis, D. and Jimenez, R. May 2016. "Next Generation Foundations for Special Trackwork – Phase III." DOT/FRA/ORD-16-14.
2. Davis, D., Jimenez, R., Wilk, S., Bakkum, B. November 2017. "Evaluation of Under-Tie Pads for Flange Bearing Frog Crossing Diamonds." *Technology Digest* TD17-031. AAR/TTCI. Pueblo, CO.
3. Davis, D., Shu, X., Jimenez, R., and Rael, B. November 2014. "Evaluation of a Foundation Design for Turnouts under Heavy Axle Load Traffic." *Technology Digest* TD14-022. AAR/TTCI. Pueblo, CO.

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