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

Key Findings:

- Degraded concrete ties removed from service by a Class I railroad were repaired using four repair methods.
- These test ties have accumulated over 400 million gross tons (MGT) and are providing acceptable track performance at FAST. This performance is similar to that of other concrete ties at FAST based on the results from gage strength tests, clip toe load measurements and visual inspections.

Concrete Tie Life Extension: Interim Report

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TTCI initiated an in-track test supported by the Association of American Railroads' (AAR) Strategic Research Initiatives Program to study the extension of concrete tie service life using several repair methods. In this study, a concrete tie test zone was established on the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST), Pueblo, CO, to investigate the performance of degraded concrete ties and test the effectiveness of different repair methods for concrete tie life extension.

TTCI received 200 degraded concrete ties donated by a Class I railroad in the western United States. The degraded concrete ties were removed for replacement due to the railroad's maintenance standards. The ties were visually inspected to determine each tie's category based on the surface condition, and three main types of deterioration were discovered—center cracking, rail seat deterioration, and shoulder wear. The ties with acceptable surface conditions (surface cracks only; no structural cracks running through the tie cross section) were selected for field installation. Based on this criteria, about 90 percent of ties were considered repairable. The concrete ties have accumulated over 400 million gross tons (MGT) since their installation at FAST June 2021. To date, the test ties have provided sufficient track strength and acceptable track performance similar to other concrete ties on the HTL.

BACKGROUND

Concrete ties, like other track components, degrade over time due to repeated train loads and environmental conditions. Typical failure modes observed in concrete ties include concrete cracking, rail seat deterioration, and shoulder/fastener wear. However, the level of deterioration sufficient for removal of degraded ties remains unclear. Some degraded concrete ties may be repaired in a cost-effective manner to allow the ties to reach a longer service life, and, if repair methods prove feasible and effective, railroads could reduce the lifecycle cost of concrete ties by maximizing the lives of concrete tie-and-fastener systems. Therefore, TTCI is researching the effects of degraded concrete ties on track performance and methods to repair concrete ties quickly and effectively.

CONCRETE TIE SELECTION

The concrete ties were visually inspected for categorization based on their surface condition. Those ties with an acceptable surface condition (surface cracks only no cracks running through the tie cross section) were selected for field installation. As shown in Figure 1, the ties were grouped based on four categories: light, marginal, severe, and failed.

The failed ties were not used for repair. Out of the 200 ties, 183 ties were considered repairable—82 in light condition, 89 in marginal condition, and 12 in severe condition.

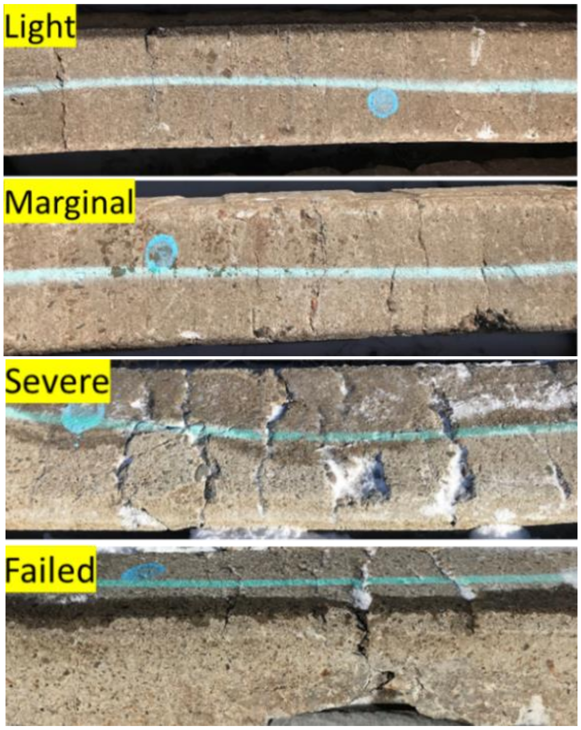

Figure 1. Tie condition categories

To provide information beyond what was gathered during the visual inspection, 12 ties (three from each category) were evaluated using the American Railway Engineering and Maintenance-of-Way Association (AREMA) center negative bending test to determine their bending capacity. Two of three failed ties did not meet the test criteria. The nine repairable ties met the test criteria recommended by the AREMA *Manual for Railway Engineering*.[1] The test results indicated that a representative sample of the repairable ties identified during the visual inspection met AREMA bending strength recommendations. Since over 90 percent of the ties were considered repairable, it may be concluded/assumed that many degraded in-track concrete ties currently being replaced may still have sufficient bending strength to perform in service.

CONCRETE TIE REPAIR

The 174 ties chosen were repaired before being installed on a 5-degree curve on the HTL. The repair methods included center cracking repair, surface patching, rail seat repair, and work shoulder repair (Figure 2). The repair effort was conducted on the wayside, and the ties were installed using a tie inserter.

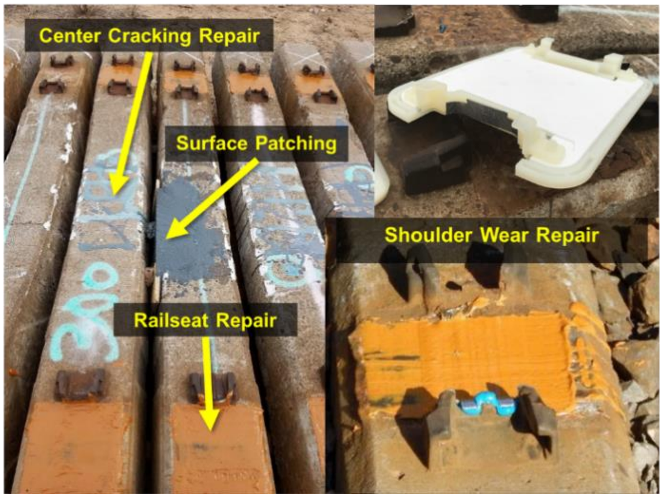

Figure 2. Concrete tie repair methods

The repair methods are described below:

- **Center cracking repair**: Two types of epoxy used as a sealant to prevent water from getting into the cracks. The ties were divided by two group and each epoxy was used for one group.
- **Surface patching:** Cementitious mixture used to replace missing concrete chunks on the tie surface. The missing chunks were not deep enough to expose rebars. This method focused on preventing water ingress and restoring compressive strength to the top portion of the tie.
- **Rail seat repair:** Epoxy applied to the rail seat to restore cant and toe load.
- **Worn shoulder repair:** Applied epoxy to repair the worn shoulder. Since the ties were pulled from a tangent track and did not have much shoulder wear, representative shoulder wear was simulated by grinding the shoulder on the field side of the high rail to match documented curve-worn shoulders. Besides being a conventional method of worn shoulder repair,

a newly designed rail pad (Figure 2, top right corner) with a built-in steel shim to hold the repair material in place provides both easy and conventional methods of worn shoulder repair.

Table 1 shows the number of ties assigned to each repair method. The repaired ties were installed in September 2018. They have accumulated over 400 MGT as of June 2021. Long-reach McKay-style clips and heavy duty insulators were also installed for this test.

Table 1. Number of ties for each repair method

Center Cracking	Surface Patching	Rail Seat	Worn Shoulder
165	6	174	20 (conventional way) 20 (newly designed rail pad)

TRACK PERFORMANCE

Track Gage Strength

To assess the track gage strength, TTCI's Track Loading Vehicle (TLV) ran through the test zone before train operations began (0 MGT). The TLV ran at 20 mph with a 33-kip vertical wheel force and an 18-kip lateral gage widening force. Both the loaded and unloaded gage were recorded throughout the test (Figure 3). About 0.4 inch of gage widening was generated by the TLV; consistent with other concrete tie zones on the same curve.

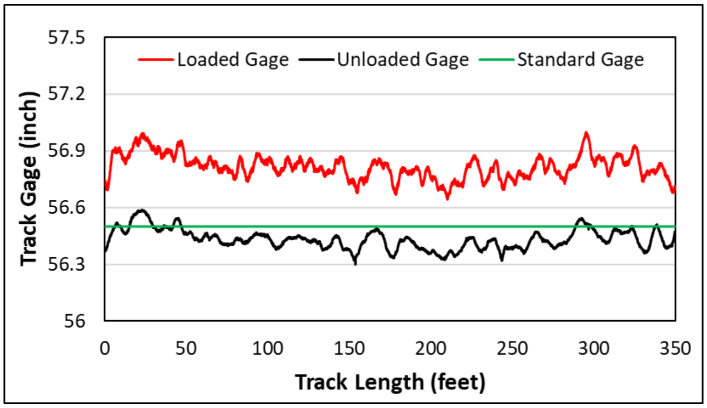

Figure 3. Loaded and unloaded track gage

Gage strength testing using a lateral track loading fixture (LTLF) was conducted every 50 MGT since the installation of the test section. Twelve concrete ties throughout the test zone were selected for testing. The LTLF was used to apply a 9-kip gage spreading force at both the rail head and rail base. As shown in Figure 4, for the head applied loads, the average gage widening of these 12 ties at the rail head started at 0.15 inch at 0 MGT and fluctuated in the range of 0.15 inch to 0.19 inch during the test period—typical measurements for concrete tie-fastener systems that are performing sufficiently.

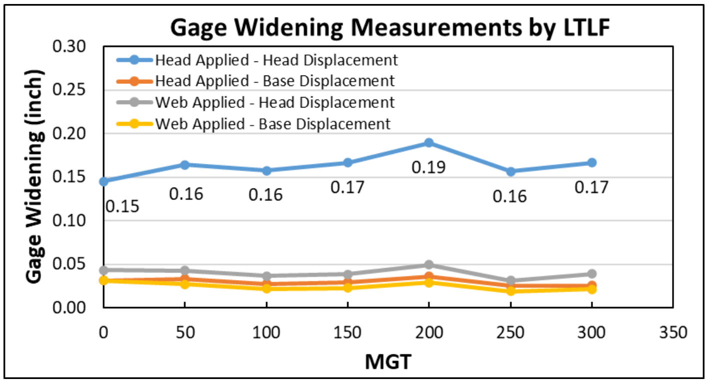

Figure 4. Gage widening measurements by LTLF every 50 MGT

This amount of the fluctuation in the gage widening is considered small and could be caused by longitudinal forces in the rails, the testing device, track maintenance, etc. The gage strength of this test section was comparable to that of other concrete tie sections on the same curve. Therefore, the degraded concrete ties showed consistant track gage strength over 400 MGT.

Clip Toe Load

Clip toe load measurements were conducted every 50 MGT as well. Using a portable reaction frame, toe load was measured on the same 12 ties as the LTLF test. The average toe load decreased by 9 percent after 50 MGT and by 17 percent after 100 MGT. The toe load remained consistent after 100 MGT (Figure 5). Although both gage strength and toe load showed some reduction, the gage holding capacity and clip strength are still acceptable for track performance.

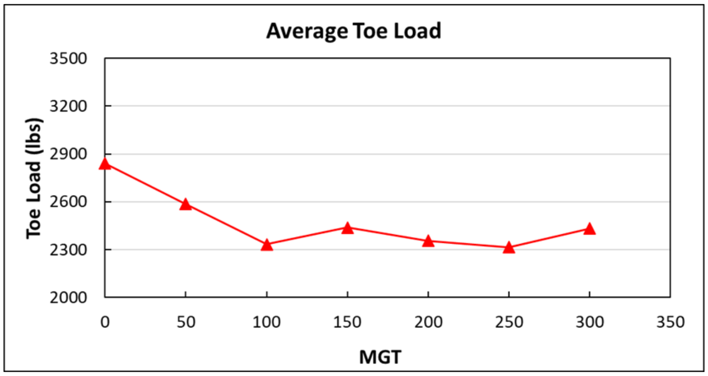

Figure 5. Average clip toe loads every 50 MGT

Surface Condition Inspection

Two types of epoxy were used to seal the surface cracks on the concrete ties. The goal of this repair method is to prevent further cracking/damage due to water penetration, not add structural reinforcement/strength to the tie. Two main observations were made regarding the performance of the epoxy center crack repairs (Figure 6). First, neither epoxy prevented new cracks in the concrete ties—new surface cracks developed despite the presence of both epoxies. Second, both shelling and cracking were found on the tie surfaces after epoxy application. In fact, 30 percent of the ties repaired with one epoxy had cracking or shelling while 10 percent of ties repaired with the other epoxy had cracking or shelling.

Regarding shoulder wear repair including the newly designed rail pads, the repaired section appears to be performing well thus far. One tie with surface patching repair had cracking on the repair found at 400 MGT.

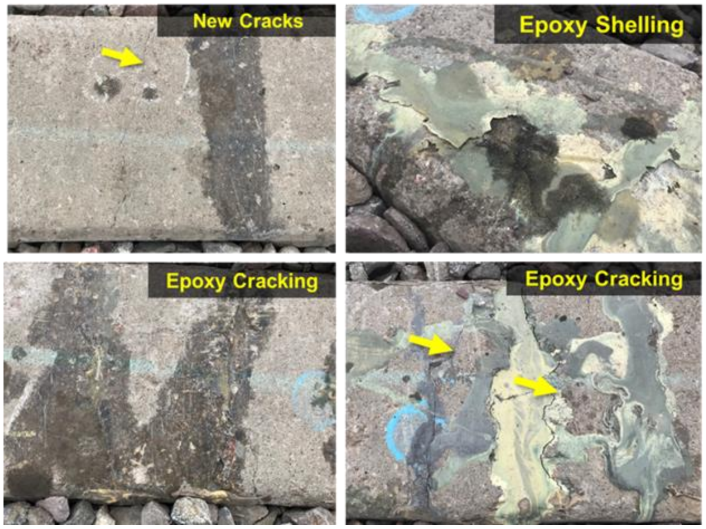

Figure 6. Condition of center cracking repair

Moreover, freeze/thaw cycle testing was conducted on nine ties without center cracking repairs and 10 ties with the repairs. Water was poured on the surfaces of all 19 ties (both repaired and non-repaired) to generate about 30 freeze/thaw cycles during the winter. In general, there was no obvious change in the tie surface condition for either the repaired or non-repaired ties. In fact, the number of cracks and the crack length and width had little change for the nine ties without center cracking repairs. While the arid weather in the test area may ease the concrete water damage and 30 artificial freeze/thaw cycles may not be enough to draw conclusions, the ties will continue to be inspected as more freeze/thaw cycles are generated.

CONCLUSIONS

The repaired concrete ties accumulated over 400 MGT as of June 2021. To date, the test ties have provided sufficient track strength and acceptable track performance similar to other concrete ties on the HTL. Results, to date, indicate that many degraded concrete ties currently being replaced may still meet AREMA bending strength recommendations and, with some moderate level of repair, may continue to provide acceptable track performance. Additional findings include:

- Both the TLV and LTLF measuments showed similar gage strength compared to the other concrete tie test zones on the same curve.
- Average toe load decreased 9 percent after 50 MGT, 17 percent after 100 MGT, and stayed the same from 100 MGT forward.
- Shoulder wear repair performed well.
- One tie with surface patching repair cracked.
- Epoxy shelling and cracking were found on ties with center cracking repair.
- No obvious difference found on the degraded concrete ties after 30 freeze/thaw cycles.

ACKNOWLEDGMENTS

TTCI gratefully acknowledges the support from the AAR SRI Program–Tie and Fastening Systems, and the railroad that provided the concrete ties and repair materials for this test.

References

1. American Railway Engineering and Maintenance-of-Way Association, *AREMA Manual for Railway Engineering*, Landover, MD, 2019.

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