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IMPACT OF WATER ON CRACKED CONCRETE CROSSTIE SERVICE LIFE

SUMMARY

This report is part of a larger project, Improved Concrete Crossties and Fastening Systems for U.S. High-Speed Rail and Joint Passenger/Freight Corridors, funded by the Federal Railroad Administration (FRA). The University of Illinois at Urbana-Champaign (UIUC) conducted this research between 2015 and 2019 at its Rail Transportation and Engineering Center (RailTEC) laboratories.

Track with inadequate support conditions at the tie ends can lead to center cracking in concrete crossties. These cracks form at the top surface of the crosstie. The presence of moisture in these cracks can exacerbate the damage (**Figure 1**). To investigate the impact of moisture on crack growth and other tie damage, UIUC researchers subjected pretensioned concrete crossties and small-scale beams to repeated loading conditions with water added to the system.

Figure 1. Center-cracked concrete crosstie

Laboratory results revealed that cracked pretensioned concrete crossties have a shorter cyclic life when water is present when compared to crossties tested under dry conditions.

BACKGROUND

The presence of center cracks in concrete crossties is not uncommon. Research shows that these flexural cracks do not reduce the overall strength and life expectancy of the crosstie [1]. In other industries, prestressed concrete beams can be designed to crack in service [2]. In railroad track, these cracks will open and close in response to bending loads and may grow larger if water and concrete fines are present (**Figure 2**).

Figure 2. Severely deteriorated crossties in track

Railroad crossties are subjected to varying weather conditions and it is inevitable that cracks will be exposed to water. Any water accumulated inside the cracks would be expelled (or trapped) when the prestressed tendons force the cracks to close after each axle pass. Therefore, there is water flow in cracks that may cause concrete deterioration. Over time, this condition may affect the structural capacity of a concrete crosstie and reduce its service life.

OBJECTIVES

This research investigated, experimentally, the effect of water on the damage rate of cracked concrete crossties. In particular, the research goals were to:

- Quantify water pressure within cracks.
- Quantify cyclic life of cracked concrete crossties exposed to water.

The results of this research contribute to the overall scientific body of knowledge and will aid in the development of objective and scientific criteria for concrete crosstie track maintenance.

METHODS

UIUC experimented with small-scale specimens (prisms) and full-size concrete crossties. These were initially loaded to generate cracks and then cyclically loaded to investigate the role of water in the deterioration of pretensioned concrete with flexural cracks. Some prisms were submerged in water to create a severe condition to bound the problem (**Figure 3**), and transducers were used to measure water pressure in cracks (**Figure 4**). UIUC tested full-size crossties in more realistic moisture conditions (**Figure 5**) during cyclic, four-point bending tests (**Figure 6**).

Figure 3. Submerged prism in water tank

The pretensioned prisms were designed to model concrete crossties, and were based on the work of Momeni et al. [3]. They had a square cross-section with sides at 3.5 inches (88.9 mm) using four steel wires pretensioned to 7 kips (31.1 kN). The ratio of steel to concrete in the cross-sectional area was similar to concrete crossties at their center section. The prisms were 42 inches (1,067 mm) long, to ensure that the development length of the compressive force did not extend into the test span.

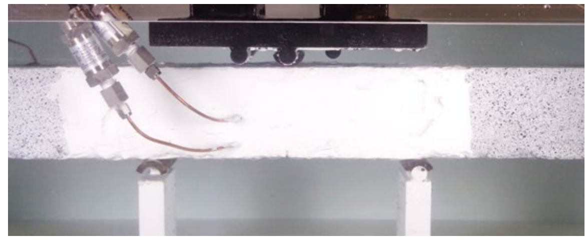

Figure 4. Pressure gauges in test prism

The prism experiments helped to bound the range of experimental results and to assess the hydraulic pressure in cracks. Researchers then tested five identical pretensioned concrete crossties. One tie was tested dry, two ties were subjected to a constant water spray, and two ties were subjected to a periodic water spray (1 hour on, 5 hours off).

Figure 5. Water spray on concrete crosstie

All crossties were loaded in the same four-point bending configuration, corresponding to AREMA's recommendations [4]. The peak load was 70 percent of the crosstie's ultimate flexural capacity. This high load level reduced the number of test cycles when water was added while still maintaining infinite life for dry crossties. Finally, additional crossties of different designs were tested to obtain more general results.

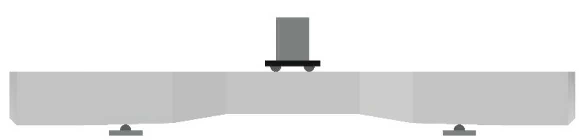

Figure 6. Four-point bending test configuration

RESULTS

On average, the dry prism absorbed twice as many load cycles before failure compared to submerged prisms. When prisms equipped with pressure gauges were loaded, a cyclic water pressure signal was observed (**Figure 7**).

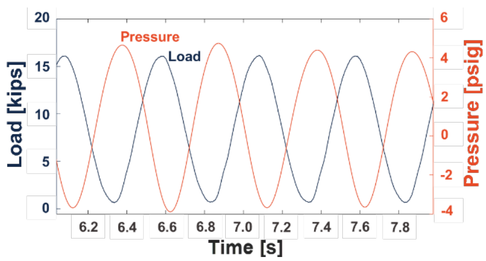

Figure 7. Water pressure in crack during cyclic loading

The water pressure inside the crack reaches a peak when the external load is low and the prestress forces closed the crack. The lowest water pressure readings aligned with the applied load peaks when the external forces opened the crack and allowed water to fill the voids. The maximum values of in-crack water pressure (approx. 4 psi) are two orders of magnitude lower than the expected tensile strength of concrete (approx. 700 psi), indicating that water pressure alone is insufficient to damage the concrete.

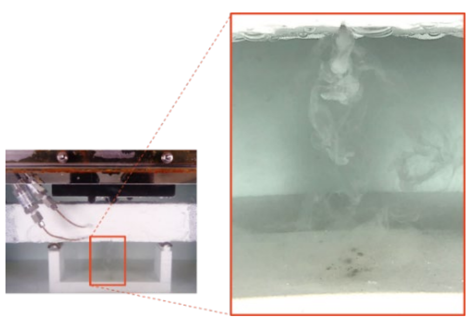

Figure 8. Debris expelled from crack during test

However, researchers observed concrete debris flowing from the crack, which was not seen in dry conditions (**Figure 8**). This indicated that abrasion and erosion occurred during the loading cycles, and these mechanisms may have been the root cause of the deterioration that resulted in the premature failure of the prisms.

The full-size crosstie test results were consistent with the prisms. The dry-loaded crosstie test was stopped at 11 million cycles. No signs of impending failure were observed, indicating an infinite fatigue life under these conditions. The two crossties tested under a constant water spray failed after only 1.01 and 1.68 million cycles. Large cracks were formed in these ties, and the cracks turned to the horizontal direction, following the prestressing wires (**Figure 9**). Finally, the two crossties subjected to a periodic water spray failed at 1.56 and 0.57 million cycles. The abnormally short life of this last tie may be explained by an unfavorable combination of random variables in manufacturing (e.g., change in prestress centroid, low local concrete strength, etc.). The results, however, generally agree with the observations from prisms—the presence of water reduces the cyclic life of cracked pretensioned concrete crossties.

Figure 9. Horizontal cracks along prestress rows

The test results from concrete crossties of different designs yielded similar degradation patterns, aggravated by the introduction of water. When cracks followed the first layer of prestressing wires, failed crossties (**Figure 10**) were similar to field observations (**Figure 2**).

Figure 10. Crosstie with exposed wires after test

CONCLUSIONS

These experiments demonstrate that concrete ties can degrade more quickly if water is present. The fatigue life of concrete ties is greatly reduced when water is introduced to standard four-point bending tests. The experimental results do not appear sensitive to the amount of water added to the system.

RECOMMENDATIONS

To realize a maximum in-service life of concreate ties, railroads and concrete tie manufacturers should strive to design and manufacture ties that do not crack under in-service loads, especially in areas with high precipitation. The application of the results of this study will contribute for greater overall safety and durability of pretensioned concrete crossties. Additional research is needed to determine the effects of water on post-tensioned, un-bonded crossties.

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A full examination of this and related topics is provided in UIUC report, “Flexural distress and degradation mechanisms in pretensioned concrete beams and railroad crossties.” The permanent web address is http://hdl.handle.net/2142/108267 (available August 2022).

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KEYWORDS

Concrete crossties; water damage; center cracks; cyclic loading