FTA RESEARCH
FEDERAL TRANSIT ADMINISTRATION

REPORT SUMMARY

U.S. Department of Transportation
Federal Transit Administration

Resilient Concrete Crosstie and Fastening System Designs for Light, Heavy, and Commuter Rail Transit

Background

To further improve on the means and methods by which rail transit track systems are designed, research was undertaken focusing on the behavior of rail transit track infrastructure. One of the most critical components in the transfer of load through the track system is the crosstie. Concrete is the dominant crosstie material choice for rail transit applications where safety and reliability of infrastructure is at a premium and maintenance time is often limited. An industry-wide survey indicated that millions of concrete crossties and elastic fastening systems are presently in service in the US, with many more planned for use in future rail lines and rehabilitation projects.

Objectives

The objective of this project was to design, develop, and deploy field instrumentation to answer a variety of critical questions regarding the loading demands on current track systems. The objective of instrumentation was to optimize crosstie design for rail transit applications to reduce both initial capital cost and recurring maintenance expenses. Data collected at field installations throughout the US were used to quantify wheel-rail interface loads, concrete crosstie bending moments, and rail deflections under revenue service train passes. These data allowed researchers to investigate the effects of wheel condition, thermal gradient, axle load, axle location, support condition, and rail transit rolling stock and mode on crosstie bending moments.

Findings and Conclusions

A design process for rail transit concrete crossties based on structural reliability analysis concepts was developed for improved optimization and cost effectiveness of future designs.

Impact load factor distributions for the three rail transit systems studied were statistically different, demonstrating that unique load factors are needed to adequately represent the existing wheel loads and improve the design of critical components that make up the track structure. Distributions indicate that the current AREMA concrete crosstie impact factor of three could be reduced by as much as 50%.

Dynamic load factors were analyzed, and it was found that the existing Talbot approach to estimating dynamic loading due to speed and wheel diameter was a poor predictor of rail transit loads. This method over-estimates light rail transit wheel loading environment by a factor of three. Conversely, heavy rail transit wheel loading factors are underestimated by approximately 50%. The Talbot method was, however, a good predictor for commuter rail transit wheel load factors. Going forward, focused wheel-rail interface instrumentation can be deployed in the field to answer loading questions within a given rail transit mode.

A non-destructive instrumentation method using concrete surface strain gauges was successfully developed and deployed to measure bending strains and resulting moments experienced by concrete crossties under a variety of types of rail infrastructure in the US. This method was robust and yielded reliable and repeatable results over long time durations (up to three years) with very few in-service failures.

Crosstie bending moments vary widely from crosstie-to-crosstie with maximum center negative bending moments ranged from 25 kip-in (2.8 kNm) on MetroLink (light rail) to 120 kip-in (13.5 kNm) on NYCTA (heavy rail). Significant residual flexural capacity was also found. Bending moments in the 99th percentile resulted in residual load factors of 6 and 2 for light and HRT systems, respectively. Bending moments experienced by concrete crossties on rail transit systems varied from crosstie-to-crosstie, ranging from as little as 10% for center negative (C-) bending on MetroLink to as much as 100% on NYCTA. Crosstie-to-crosstie variability between the two transit modes was also quite different, with the greatest variability associated with heavy rail transit center negative bending moments.
A prototype crosstie was designed for light rail transit infrastructure and installed on St. Louis MetroLink. This design was based on results from field instrumentation installations, through the use of a variety of analytical methods. Performance has been encouraging to date, and monitoring will continue beyond this project duration.

Benefits

New (proposed) designs for rail transit concrete crossties are more economical, having a center negative moment capacity reduction of 50% for heavy rail transit. In most cases, the proposed designs for both rail modes have fewer prestressing wires and a higher centroid of prestressing steel. In all cases, the flexural capacities at the crosstie center and rail seat are better balanced from a structural reliability standpoint. This framework for probabilistic design provides a foundation for the future application of mechanistic-empirical design practices to other rail transit track components.

Project Information

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This research project was conducted by the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign (Illinois). For more information, contact FTA Project Manager Terrell Williams at (202) 366-0232 or Terrell.Williams@dot.gov. All research reports can be found at **https://www.transit.dot.gov/about/research-innovation**.