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Concrete Crossties: A New Paradigm for Design

Written by J. Riley Edwards and Marcus S. Dersch and Arthur de Oliveira

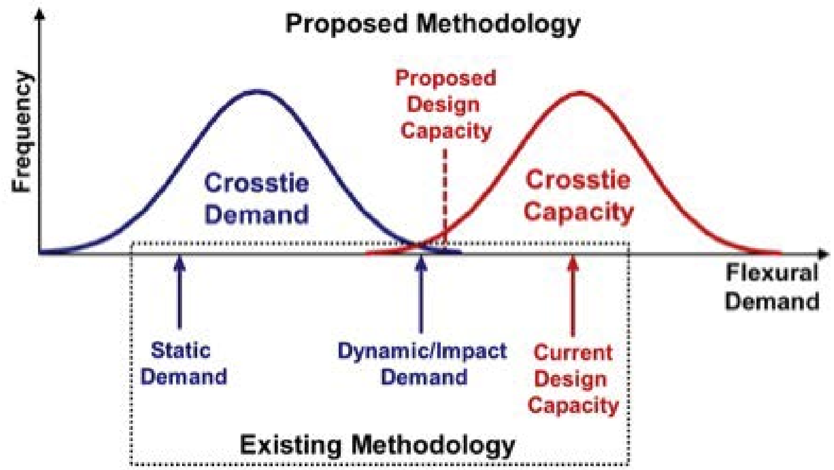
Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign

Researchers in the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign have been actively conducting research and engaging with industry experts in an effort to improve the methods used to design a variety of track infrastructure components. Nowhere has this been more evident, and timely, than RailTEC's research to improve the current concrete crosstie design practices.

In North America, concrete continues to be a dominant crosstie material choice for demanding locations on heavy axle load (HAL) freight railroads with steep grades, sharp curves, and high annual gross tonnage. Concrete crossties are also used with increasing frequency for rail transit applications where safety and reliability of infrastructure is at a premium and maintenance time is often limited. To date, there are over 35 million concrete crossties installed in North American rail infrastructure with manufacturing capacity to produce multiple millions of additional ties annually. Given the magnitude of their current use and likely increase going forward, as some of the earlier installations reach the end of their 50-year design life, the development of a structural design method that enables optimization of crosstie design for varied applications and loading environments will reduce initial capital cost and recurring maintenance expense.

The problem

Presently, and to the surprise of many end users, concrete crossties are largely designed using an outdated understanding of what demand is likely to be placed on them in the field. These designs are generated using a variety of factors that are applied to a static axle load. This has led to either premature service failures or crossties that are overdesigned, wasting scarce capital resources. Two of the most common forms of



failure are a result of the flexure, or bending, of the crosstie under load. Center flexural cracking is one of the most common factors limiting the service life of concrete crossties in North America, and rail seat cracking has also been documented as a performance concern. Improving the understanding of **crosstie flexure** can help reduce the occurrences of cracked crossties by ensuring that designs conform to the field conditions in which they are used. But what are these flexural demands?

To date, few methods have been proposed to accurately quantify concrete crosstie revenue service field flexural demand. In addition to the quantification of bending moment magnitude, it is important to understand their variability from crosstie-to-crosstie due to support conditions and other factors. Thanks to funding from FRA, FTA, and the private sector, instrumentation was deployed on Amtrak's Northeast Corridor, MTA – New York City Transit Authority, Metra (Chicago, IL), MetroLink (St. Louis, MO), and HAL freight railroads to quantify the demands on these components while also validating a method to quantify crosstie bending moments using concrete surface strain gauges.

The method

Data collected using this method at eight different field installations throughout the United States were used to investigate the effects of axle load (loaded versus empty), ballast support condition (well-supported versus center-bound), crosstie thermal gradient (differential temperature between the top and bottom of the crosstie versus uniform temperature), and other variables on crosstie bending demand. Results indicated is from crosstie's thermal gradient is significant and should be considered in crosstie flexural design, especially at the crosstie center. Additionally, crosstie support condition is the largest source of variability in crosstie bending moments and its effect is most pronounced on HAL freight railroads.

The field results indicated the need for development and application of a probabilistic design method for the flexural capacity of concrete crossties. A probabilistic method is one that considers the distribution of possible demands placed on a crosstie in the field, as opposed to making a discrete assumption using a fixed value (also known as a deterministic approach). Such a method was more broadly proposed within the rail industry by Dr. John Samuels in the early 2000s to qualitatively describe the “stress state of the railroad.”

Proposed designs, based on the development and application of a probabilistic design method of the concrete crossties, are more economical. A probabilistic process facilitates quantification of any potential risk associated with a crosstie design. Proposed designs can have a center negative moment capacity reduction of as much as 50% for certain rail transit applications. For HAL freight, a reduction in rail seat bending capacity of approximately 40% is justified, noticeably reducing the size of the rail seat cross section. In all cases the flexural capacities at the crosstie center and rail seat are better balanced from a structural reliability standpoint. This means that the safety factors at each of these critical locations are closer to one another, indicating the design is more balanced from a safety and service life point of view. In most cases the proposed designs have fewer prestressing wires (a costly element of crosstie manufacture) and a modified center of gravity of prestressing steel. Reductions in costs of crossties could allow funding to be re-allocated to other resilient track components such as under tie pads, further increasing the overall track system life cycle.

This proposed method is not merely hypothetical. Elements of the process developed by **RailTEC** have been used to design a new generation of concrete crossties for Amtrak’s Northeast Corridor and light and heavy rail transit applications. To date, crossties have been designed, fabricated, and installed in the field for revenue service field testing and further data collection, with positive preliminary results. This probabilistic design framework provides a foundation for the future application of mechanistic-empirical design, which is already used in the design of pavements, for other railway track components.

The team of researchers and practitioners

This project has been a success due to strong industry support in the form of research funding provided by the Federal Railroad Administration (FRA) and the Federal Transit Administration (FTA), two modal administrations of the United States Department of Transportation (US DOT) that are critically aware of the needs to improve the current state of good repair of our infrastructure. Additional support was provided by Union Pacific Railroad; BNSF Railway; National Railway Passenger Corporation (Amtrak); Progress Rail Services, a Caterpillar Company; Gutanna Technologies; Hanson Professional Services, Inc.; Rocla/Vossloh Concrete Ties and Fastening Systems; voestalpine Nortrak; and CXT Concrete Ties, Inc., an LB Foster Company.