Investigation of the Causes of Transverse Bridge Deck Cracking

tech transfer summary

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RESEARCH PROJECT TITLE
Investigation of the Causes of Transverse Bridge Deck Cracking

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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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This project investigated factors that lead to the formation of early-age transverse cracks in concrete bridge decks for mitigation in the future.

Research Objective, Focus, and Scope

The goal of this research was to identify factors that consistently lead to the formation of early-age transverse cracks in concrete bridge decks so that they can be mitigated in the future.

Problem Statement

The causes of early-age bridge deck cracking are not entirely understood. Because of the large number of factors involved, it is difficult to evaluate the contribution of each factor individually. Some research indicates that bridge deck cracking is the result of a combination of factors in different categories, and additional, extensive research is needed to quantitively identify the effect from each factor.

Project Background

Iowa Department of Transportation (DOT) bridge staff have noticed multiple recent occurrences of transverse deck cracks developing shortly after bridge construction. This situation is very problematic because the cracks can provide a direct pathway for the intrusion of water and chlorides. In the worst case, these early-age cracks can speed up corrosion of the reinforcing steel, deteriorate the deck concrete, and eventually lead to increased maintenance costs and a reduced bridge deck service life.

Over the past several decades, numerous studies have been conducted on the causes of transverse bridge deck cracking. In general, the factors can be categorized into three groups: structural design factors, construction and environmental factors, and material and mix design factors.

Unfortunately, the causes of transverse deck cracking remain unclear, and the problem persists. Sometimes, the results from different research studies contradict each other, indicating that further research is needed.

Early-age transverse deck cracks on two Iowa bridges

Research Description

The research started with a detailed literature review of conditions (environmental, structural, material, etc.) to help identify the factors consistently "in play" when early-age transverse deck cracks are formed.

To obtain a comprehensive evaluation and include as many potential factors as possible while still keeping the research manageable, the primary research investigation was conducted in three stages with varying numbers of bridges and factors studied in each stage.

The first stage of the investigation was carried out based on the use of a ready-made database provided by the Iowa DOT. These data, which were combined in the form of an Excel spreadsheet, included information on 2,675 bridges across the state.

The bridge deck crack information used in this stage was obtained primarily from the Structure Inventory and Inspection Management System (SIIMS) database maintained by the Iowa DOT, and each bridge deck was categorized as either cracked or uncracked based on inspection notes and images. The parameters studied in this stage included deck concrete type, maximum span length, maximum structure length, bridge location, bridge age, and main structure type.

The second stage of the investigation was conducted to include additional bridge parameters into this study. A smaller group of 20 bridges was selected after reviewing inspection reports for 116 bridges constructed between 2013 and 2018.

After that, the bridge data were collected and sorted into three main categories, structural, construction, or material, and the Bridge Engineering Center's crack rate equation, which used average span length rather than bridge length, was utilized to calculate the crack rate for each bridge. Furthermore, the research team analyzed the results to establish the relationship between the crack rate and each studied factor.

Underside bridge deck image similar to those in DOT inspection reports near the pier and above the pile cap from a field visit

Concrete deck placement in Iowa like that observed and studied for construction factors as part of this study

The third stage of the investigation was carried out based on data collected starting with deck concrete placement from six field visits. The parameters investigated in this stage included evaporation rate (lb/ft²/h), air temperature (°F), concrete temperature (°F), relative humidity (%), and wind speed (mph).

During each field trip, a form was used to record the basic bridge information and the on-site construction data. The crack rate for each bridge was later calculated utilizing the Bridge Engineering Center's crack rate formula and used to characterize the relationship to each studied factor.

In addition, the results from all three investigation stages were compared with the results from previous information collection conducted by the Iowa DOT (Yusuf and Nop 2022). Similarities and differences in the findings between the work conducted by the authors and previous researchers were also evaluated.

Key Findings

- High-performance concrete (HPC) bridge decks showed a higher chance of cracking compared to non-HPC bridge decks
- Iowa DOT Districts 4 and 6 in southwest and east Iowa, respectively, had a higher propensity for having cracked bridge decks
- Precast, pretensioned concrete beam (PPCB) bridges showed a higher chance of deck cracking than steel beam bridges
- Type 1 and IP (portland-pozzolan) cement showed a higher chance of deck cracking compared to that for Type 2 cement
- Bridges constructed between 1960 and 1980 showed a higher chance of deck cracking
- Based on the data recorded from six concrete bridge deck placements, a high evaporation rate resulted in a higher chance of deck cracking

Implementation Readiness and Benefits

Based on the research findings from each stage of this investigation, a final designation on the relationship between each bridge parameter and deck cracking was made as either direct correlation, no correlation, slight positive correlation, or slight negative correlation. The term positive indicated the crack rate increased as the magnitude of the studied factor increased, and negative indicated the crack rate increased as the magnitude of the studied factor decreased.

- No correlation could be established between the crack rate and structure length, maximum span length, air temperature, concrete temperature, relative humidity, structure age, coarse aggregate content, or fine aggregate content
- A slight positive correlation with a low confidence level could be established between the crack rate and girder spacing, span length-to-girder spacing ratio, top transverse reinforcement, cement content, air content, and average wind speed
- A slight negative correlation with a low confidence level could be configured between the crack rate and girder depth, girder-to-deck stiffness (EI) ratio, bottom transverse reinforcement, concrete strength, fly ash, concrete slump, and water-to-cement (w/c) ratio

The summaries shown in Table 16 and Table 17 of the final report for this project can help Iowa DOT bridge deck engineers and also aid Iowa DOT research staff in deciding about future research work to pursue.

Reference

Yusuf, A. and M. Nop. 2022. *Investigation of the Severity of Full Depth Transverse Bridge Deck Cracking of State-Owned Beam Bridges in Iowa Constructed from 2015 to 2019*. Iowa Department of Transportation, Bridges and Structures Bureau, Ames, IA.