



PUTTING RESEARCH TO WORK

BRIEF

What's Causing Cracking in New Bridge Decks?

Cracking in bridge decks accelerates the penetration of water, sulfates, chloride and other corrosive agents through the concrete where they can damage the steel reinforcement, which leads to deterioration of the concrete structure as a whole, requiring costly maintenance and repair. Though cracking is a long-standing and notoriously difficult problem, in recent years more bridges are developing cracks almost immediately after being put into service rather than later as a result of traffic loads. A recent NCHRP study found more than 100,000 bridges in the United States suffer from early-age transverse cracks, and Wisconsin is no exception.

What's the Problem?

Recently built bridges in Wisconsin are developing early-age transverse and map cracks in the concrete overlays, leading to increased maintenance and repair costs. WisDOT needed to understand the extent of this problem, why this cracking is occurring and what options were most promising to address the problem.

Research Objectives

The objectives of this research were to identify the key factors that cause early-age cracking in concrete bridge decks in Wisconsin and to provide recommendations to reduce or eliminate such cracking.

Methodology

Researchers reviewed the available U.S. and international research findings to determine the current state of knowledge about the various components that contribute to early-age bridge deck cracking.

Then they analyzed 15 bridges recently built in the Milwaukee area using 21 variables thought to contribute to deck cracking. They also visually inspected 16 older bridges in the area, focusing attention on the role of bridge superstructure in the development of cracks.

Researchers also quantified and studied the effects of concrete shrinkage and traffic-induced strains in developing deck cracks, using finite element analysis computer modeling.

Finally, they performed concrete-property analysis of two newly constructed bridges in Milwaukee by casting sample cylinders of the concrete used in the overlays during construction and testing them as they cured at the structural testing lab at Marquette University.

Results

Analysis of the Milwaukee area bridges showed that the main variables indicated as promising parameters in the literature had little correlation with the cracking that occurred. Unfortunately, some important data for the structures such as the specific proportions of constituents in the concrete mixes, properties of the hardened concrete, the time and location of crack initiation, and traffic data were not available for analysis. Visual inspection of the older bridges showed that superstructure configuration is important, but the gathered data set was not detailed enough to make definitive conclusions regarding superstructure type other than that continuous superstructures, which include a single, uniform deck overlay with one or more piers supporting the bridge in the middle, appear more susceptible to deck cracking than simply supported spans, which have no piers.

With this project, researchers completed one of the first detailed, quantified computer models (finite element analysis) of the stress effects of concrete shrinkage. Concrete can shrink considerably as it dries and cures, which, when the material is restrained from movement as it is on a bridge deck, results in internal stresses that can rupture the concrete. Any cracks of this sort will likely occur within four to six days after pouring the concrete and will usually be invisible to the naked eye. The cracks widen

Investigator



"The tensile stress induced by concrete shrinkage can cause bridge deck cracking, even before the traffic starts."

—Baolin Wan
Marquette
University
baolin.wan@
marquette.edu

Project Manager



"This project is really the beginning of a new phase of looking closely at early-onset cracking in concrete overlays and how to alleviate the problem."

—Travis McDaniel
WisDOT Bureau of
Structures
travis.mcdaniel@
dot.wi.gov

Co-investigator:
Christopher Foley,
Marquette University

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CTC & Associates LLC
ctcandassociates.com



Researchers examined the causes of cracks that plague concrete bridge decks and overlays soon after construction. Pictured here is a typical map-crack, in which the crack extends along the bridge's length and width.

and become more visible under traffic. The study found the development of high internal stresses to be correlated with the rapid development of concrete strength while curing.

In the analysis of post-pour concrete from two new bridges, the compressive strength of the concrete developed very quickly in the first few days, increasing the likelihood of early-age cracking on the decks.

Researchers recommended that any method that can reduce concrete shrinkage should be employed to reduce early cracking. Specific recommendations from the literature reviewed for this study to reduce the total concrete shrinkage included:

- Applying curing compounds as quickly as possible and covering the concrete to prevent excessive evaporation.
- Limiting the amount of cement to 600 pounds per cubic yard of concrete.
- Keeping the water/cement ratio less than 0.4, the total percent volume of cement and water to less than 27.5 percent, and the total air content of the concrete above 6 percent.

Other recommended measures to further minimize internal stresses on the concrete overlay were:

- Pouring upward flexing regions of the deck first to limit the peak displacement of the concrete.
- Pouring no slower than 0.6 span lengths per hour to minimize the effect of new pours on the curvature of the previously cast concrete.
- Using a top reinforcement clear cover of 2.5 inches.

Further Research

Many interlocking parameters affect cracking in concrete, including early-age cracking. Researchers recommend further study to focus on isolating the contributions of individual parameters, particularly concrete strength, concrete cover thickness, overall deck thickness and type of superstructure support.

Additionally, WisDOT has joined the \$1.5 million pooled fund project, "Construction of Crack-Free Bridge Decks," TPF-5(174) (<http://www.iri.ku.edu/projects/concrete/phase2.html>), led by Kansas DOT, which is closely examining concrete cracking in bridge decks.

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Daniel Yeh, WisDOT Research and Communication Services