Research Brief

Wisconsin Highway Research Program
Project 0092-14-01
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Reflective Cracking between Precast Prestressed Box Girders

Research Objectives

- Determine the major causes of longitudinal deck cracking in adjacent precast prestressed box-beam bridges in Wisconsin
- Recommend modifying current details, specifications and methods used in bridge construction and maintenance to decrease deck cracking and extend service life

Research Benefits

- Determined that negative temperature gradient and concrete shrinkage are the leading causes of deck cracking
- Recommended changes to current overlay, abutment and grouting practices that can improve the lifespans of Wisconsin's bridge decks

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Background

Ease of construction, favorable span-to-depth ratios, aesthetic appeal and high torsional stiffness make adjacent precast prestressed concrete box-beams a popular option for short-to-medium span bridges. However, persisting durability and performance issues resulting from longitudinal deck cracking at shear key locations threaten its favorability. Deck cracking is the primary trigger of deterioration and distresses of these bridges. The goal of this project was to develop practical recommendations for modifications to current details, specifications and methods used in the construction of adjacent precast prestressed concrete box-beam bridges in Wisconsin to minimize the potential for developing longitudinal deck cracking over shear keys.

Methodology

The research team surveyed bridge maintenance engineers, industry fabricators and other state departments of transportation regarding the extent and consistency of deck cracking problems, and reviewed Wisconsin bridges that applied adjacent precast prestressed concrete box-beams. Recommendations for improved policies, design detailing, specifications and construction inspection practices were made based on the findings. Additionally, the impact of using various wearing surface types on adjacent box-beam bridge superstructure durability performance was evaluated using National Bridge Inventory data. The revised details and specifications were implemented on three bridges, one with traditional abutments and a six inch thick cast-in-place concrete slab, and the other two with Geosynthetic Reinforced Soil (GRS) abutments and two inch thick masonry overlays.

Deck cracking over the shear keys was documented shortly after construction and after five months. Refined finite element analysis was conducted by incorporating user subroutines to simulate concrete strength and shrinkage development with time. The temperature gradient effect was also investigated.

Moisture ingress through cracks and shear keys.

“The researchers’ recommendations, including revised shear key geometry, hold significant potential to improve the performance and economy of precast box section bridges” – Project Manager Bill Oliva, WisDOT

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Final report is available at: WisDOT Research website.

Results

The bridges showed improved performance but did not eliminate the longitudinal reflective cracking. All three bridge decks developed longitudinal cracking over the shear keys, with the longest cracks of each bridge ranging from 28 to 144 inches. These cracks originated at the edge of the deck over the abutments and travelled toward the mid span. Each deck also developed a large number of randomly dispersed hairline cracks, a common occurrence for overlays of that mix design.

Analysis revealed that the stresses of shrinkage and thermal gradient loads are high enough to initiate cracking in typical concrete mixes. These effects are especially prominent over supports, where maximum principal stress direction is perpendicular to the direction of traffic. The effect of shrinkage was 205 pounds per square inch (psi) for the six inch overlay and 274 psi for the two inch overlay. Combined with the thermal gradient effect, this is adequate to develop cracking over the abutments.

The bridges with GRS abutments had unrelated drainage issues, cracking at the approach pavement-bridge deck joint, and significant impact from live load.

Recommendations for Implementation

Despite the adequate overall performance of new bridges, their life-spans can be improved by employing more crack-resistant overlays, rather than the portland cement mixes currently used in six inch cast-in-place concrete slabs and two inch thick overlays. These overlays will mitigate the damaging effects of shrinkage and temperature gradient loads and prolong the life of the deck. Asphalt overlays with waterproofing membranes may also serve as an adequate alternative or complement to concrete overlays or slabs.

The researchers also offered recommendations on improving grouting practices and GRS abutments. Use of impermeable membranes is needed to abate drainage issues with GRS abutments.

This brief summarizes Project 0092-14-01,
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