DRISI

Caltrans Division of Research, Innovation and System Information

Research Notes

Geotechnical/ Structure

NOVEMBER 2021

Project Title:
Development of a deck overlay method for post-tensioned box girder bridges using Ultra-High-Performance Concrete (UHPC)

Task Number: 3646

Start Date: April 1, 2020

Completion Date: March 31, 2023

Task Manager:
Issam Noureddine
Research Program Manager
issam.noureddine@dot.ca.gov

Post-tensioned Box Girder deck rehabilitation using UHPC

This task will develop a methodology to rehabilitate post-tensioned box girder bridge decks using UHPC

WHAT IS THE NEED?

Increased and heavier traffic loading and the effects of harsh environmental conditions contribute to significant deck distress in post-tensioned box girder bridges in California. Decks in this bridge type are expected to need repair, rehabilitation, or complete replacement in the not too distant future due to concrete fatigue, freeze-thaw damage, and/or potential punching shear failure.

Since the deck forms an integral part of the superstructure load resisting mechanism a special approach is required for repair, rehabilitation, or replacement of box girder bridge decks, a recent study conducted at the University of California (UC) Davis investigated various rehabilitation strategies that involved full-depth deck replacement of post-tensioned box-girder bridges (Zhang and Chai 2019).

The numerical analyses performed in the study determined that a full-depth deck replacement approach can be problematic because it can result in the increase of the compressive stresses in the web of the box girders and downward deflections to levels that the girders were not initially designed to handle. Moreover, tensile stresses may develop at the top of the newly placed deck as a result of concrete shrinkage and truck loading. Therefore, an alternative and cost-effective means to improve the condition of the deck in box girder bridges in California is imperative.

Through partnership between Iowa State University (ISU) and Iowa Department of Transportation (DOT), it has been demonstrated

in the laboratory (Aaleti and Sritharan 2017) and in the field (Sritharan et al. 2018) that bridge deck deterioration can be mitigated and the deck lifespan significantly improved by using Ultra-High Performance Concrete (UHPC) as a deck overlay.

Using the new knowledge developed in the Iowa studies (Aaleti and Sritharan 2017; Sritharan et al. 2018; Wibowo and Sritharan 2018) and an understanding of the problems associated with full-depth removal of the decks in box girder bridges (Zhang and Chai 2019) suggests that box girder deck rehabilitation can be effectively achieved through partially removing existing concrete deck and replacing it with UHPC layer with or without incorporating additional deck reinforcement. In addition to improving the durability of the deck, added reinforcement can strengthen the deck in post-tensioned box-girder bridges.

WHAT ARE WE DOING?

To successfully develop an approach that involves localized partial deck concrete removal and replacement with UHPC with thixotropic and rapid set properties, further investigation is needed to:

1. Determine the nature and magnitude of stresses that would develop following the removal and replacement of a thin layer in the deck of single span and two span continuous structures through detailed finite element modeling.
2. Determine the maximum acceptable depth of removal and replacement of the existing deck concrete as a function of location and/or area such that the required structural section properties of the box in its final configuration is not adversely affected assuming no supplementary or temporary supports during construction.
3. Identify any special concerns that may develop from the changes of both deck and girder section properties during partial depth removal/replacement such as creep and shrinkage effects, shear transfer between old concrete and UHPC, positive/negative flexure, and resistance to punching shear.
4. Improve the understanding of and establish estimates for the fatigue and long-term effects on the bond between both old existing concrete and partial depth deck patch and the UHPC overlay, particularly under service loads, through testing of large-size box girder bridge deck overlaid with UHPC.

WHAT IS OUR GOAL?

The goal of this research is to develop the knowledge needed to establish a suitable methodology for the rehabilitation of post-tensioned box-girder bridge decks using the UHPC overlay concept by:

- Numerically investigating the effects of rehabilitating the deck on post-tensioned box-girder bridges using a UHPC overlay that involves partial depth removal and replacement of deck concrete for different bridge configurations.
- Determining the effects of an overlay using proprietary and non-proprietary UHPC mixes for deck rehabilitation application on both local deck and global girder section properties of post tensioned box girder bridges.

WHAT IS THE BENEFIT?

This research supports the California Bridges & Structure Strategic Direction #8: Balance performance, lifecycle cost, time, delivery, and risk to optimize total value. Deliverables from this study include design details, design guidelines with examples, construction specifications and quality control plan for application of UHPC overlays.

Also, the research team will develop proof-tests of a full-scale laboratory mockup(s) considering UHPC overlays with and without a layer(s) of bar reinforcement. These results will help Caltrans to optimize capital, operating, and maintenance

costs by establishing lifecycle cost analysis procedures and developing a more flexible, range-based estimating system for structures and improve the decision-making process and tools to help identify "best value" outcomes for structures (Strategies 8.1 & 8.3).

WHAT IS THE PROGRESS TO DATE?

Recent work supported by Iowa DOT has resulted in the overlay of three bridge decks (I-girder superstructures) in the State of Iowa. Based on experiences with Iowa DOT, work has begun to evaluate the impact of non-proprietary and proprietary UHPC mixes to develop a similar methodology for post-tensioned box girder structures.

As of fall 2021, small-scale tests to characterize different UHPC design mixes has begun. 3D finite element models of selected bridges used in the UC Davis research are being developed to investigate the effects of partial deck removal and replacement on the local and global structural behavior of box girders. Analytical work to design the test unit is also under way.