Use of UHPC to Rehabilitate Post-Tensioned Box-Girder Bridge Decks in California

Sri Sritharan, Ph.D. (corresponding author) – Distinguished Professor, Iowa State University, Department of Civil, Construction and Environmental Engineering, Ames, IA, USA, Email: sri@iastate.edu

Philippe Kalmogo, Ph.D. – Assistant Professor, University of New Hampshire, Department of Civil & Environmental Engineering, Durham, NH, USA, Email: Philippe.Kalmogo@unh.edu

Nayana Sreekumar – Graduate Student, Iowa State University, Department of Civil, Construction and Environmental Engineering, Ames, IA, USA, Email: nayanasr@iastate.edu

Gata Milla – Graduate Student, Iowa State University, Department of Civil, Construction and Environmental Engineering, Ames, IA, USA, Email: gata99@iastate.edu

Charles Sikorsky, Ph.D. – Research Engineer, Iowa State University, Institute for Transportation, Ames, IA, USA, Email: sikorsky@iastate.edu

Abstract

Post-tensioned Box Girder (PTBG) bridges are frequently used when spans range from 100 to 250 ft, especially in the western US. Due to aging, environmental factors, and increasing traffic load demands, the decks of these bridges are the first elements to show signs of deterioration. Replacing the deck of a PTBG bridge is difficult and costly. This paper summarizes the progress made in a research project using the UHPC deck overlay concept to rehabilitate PTBG bridge decks in California cost-effectively. To confirm the beneficial outcomes of the proposed solution, a large-scale test unit is under construction and will be tested under different loading conditions. In addition to demonstrating the benefits of using UHPC to rehabilitate PTBG bridge decks, the large-scale tests will examine the ultimate-limit state behavior of the decks rehabilitated with thin UHPC layers under positive and negative moments and their punching shear capacity.

Keywords: Post-tensioned; Box-girder; Bridge; fatigue performance; UHPC; deck; overlay

1. Introduction

The California Department of Transportation (Caltrans) owns several thousands of Post-tensioned Box Girder (PTBG) bridges as part of the state transportation system. Due to aging as well as environmental and fatigue damage, these bridges are showing signs of deterioration, primarily to their decks, which are an integral part of the PTBG section. Replacing the decks in these bridges has been shown to be problematic (1). This is because the deck removal causes additional deflections and an increase in critical stresses, which are further exacerbated due to time-dependent effects. Limiting these adverse effects would require the replacement of the deck in smaller portions and/or shoring the box girder inside prior to removing the deck. Since the damage in most of these bridges is confined to the top surface of the deck, it was proposed to remove a thin layer of old concrete from the deck and replace it with UHPC. The presentation will focus on the benefits of the new rehabilitation strategy developed to improve the condition of the California PTBG bridges and the expected outcomes from the planned large-scale tests.

2. Analytical Study

Four prototype bridges were chosen from the current inventory as represented bridges for the analytical study. These structures were built in the late 60s or early 70s and include: 1) a simple span bridge built in 1968 in Sacramento; 2) a two-span continuous straight bridge constructed in 1973 in Woodland; 3) a three-span curved bridge built in Milpitas in 2004, and 4) a three-span skewed bridge that was also built in Woodland in 1973. Through systematic analyses of all four bridges (see Fig. 1), it has been shown that using a thin layer of UHPC for rehabilitating PTBG bridge decks, following the procedure developed for using UHPC as a deck overlay material (2,3), will not introduce any significant changes to the deflections or critical stresses. In these analyses, two different scenarios were explored. The first option looked at removing a 0.25-in. thick layer from the existing deck surface and replacing it with a 1.25-in. thick UHPC layer. The second set of analyses evaluated the effects of removing a1.25-in. thick layer from the deck concrete and replacing it with the 1.5-in. thick UHPC layer. While changes in deflections and stresses are seen, they were not found to be unacceptable to place the bridges in service for at least ten years after completing the rehabilitation.

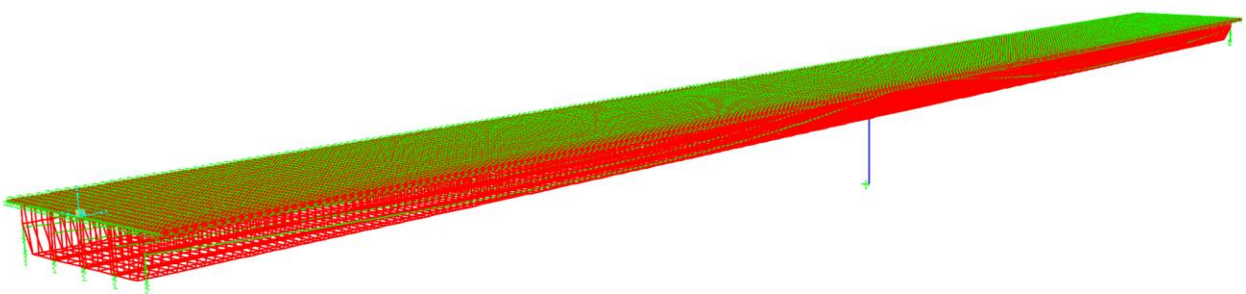


Fig. 1 Model of a two-span PTBG bridge with a thin layer of UHPC added to the deck.

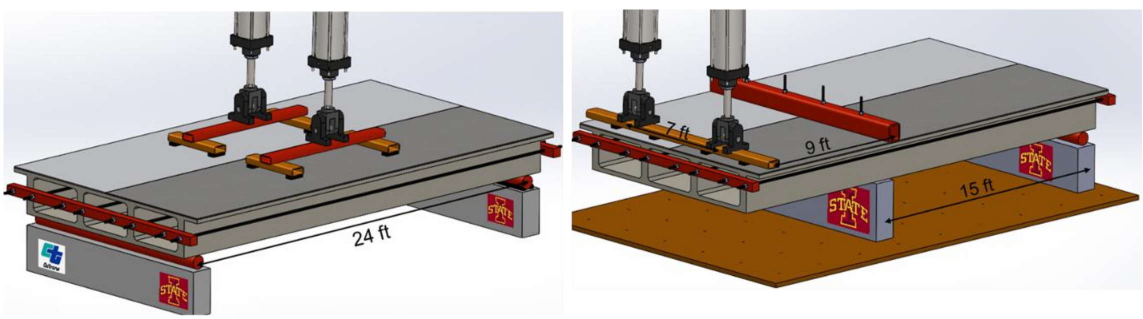
3. Experimental Plan

To confirm the results of the analytical study and ensure the bond between the UHPC and the old deck will not experience any fatigue damage, a large-scale test unit is being built at Iowa State University. The test unit was designed as a half-scale model representative of the different bridges analyzed. The unit, which consists of three cells, is 26 ft long and 14 ft wide. The test unit is post-tensioned using external prestressing bars. The test unit will evaluate the effects of the UHPC deck overlay under positive and negative moment loading. The positive moment loading will use a span length of 24 ft, while the negative moment evaluation will use a cantilever span length of 9 ft (see Fig. 2). The test unit will be rehabilitated with UHPC overlay mix from two different suppliers with no reinforcement connecting the two layers across the longitudinal joint. The test unit will be subjected to five sequences of loading. They will include:

1) fatigue loading under positive moment condition; 2) fatigue loading under negative moment condition; 3) ultimate loading under positive moment condition; 4) ultimate loading under negative moment condition; and 5) punching shear evaluation of the deck. In addition, the project investigates the quality of commercially available UHPC overlay mixes and their characteristics, including creep and shrinkage behavior.

4. Expected Outcomes

The performance of the test unit will be used to validate the assumptions used in the analyses and confirm the predicted results for the California PTBG bridge decks to be rehabilitated with a thin UHPC layer. The test results will further confirm if fatigue loading will cause damage to the interface between the old deck and the UHPC layer and the longitudinal joint between the two UHPC layers. The test will also examine how the PTBG section should be analyzed under the ultimate load condition for both the positive and negative moment conditions. The project will also examine if any reinforcements should be included within the UHPC layer, especially in the negative moment regions and possible adverse effects if this reinforcement is not incorporated.



(a) Positive Moment loading   (a) Negative Moment loading

Fig. 2 The test setup planned for fatigue load evaluation.

5. Acknowledgement

This project described herein was funded by Caltrans under Research Contract No. 65A0779. The authors wish to express their gratitude for the valuable input from the technical advisory committee received during the course of the study, as well as the contract manager, Manode Kodsuntie.

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