Advancing Bridge Repair and Preservation Using Ultra-High-Performance Concrete

by Dr. Zachary B. Haber and Dr. Benjamin A. Graybeal, Federal Highway Administration

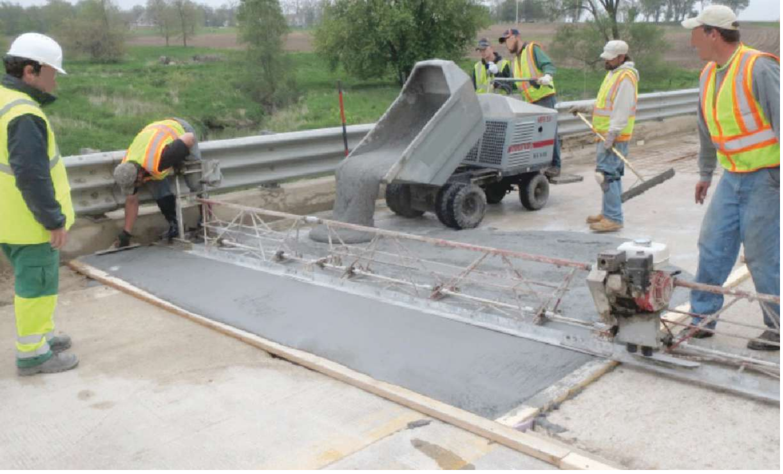
Ultra-high-performance concrete (UHPC) is an advanced, fiber-reinforced, cementitious composite material that has gained significant attention from bridge owners and designers because of its excellent mechanical and durability properties. The rapid growth in UHPC's popularity in the U.S. bridge market has been spurred in part by its ability to provide a much-needed, robust solution for closure pours in prefabricated bridge element (PBE) connections.[1] This application has also been a common entry point for owners interested in the opportunities UHPC provides for bridge design and construction. To date, in the United States, nearly 200 bridges in 27 states and the District of Columbia have been constructed using UHPC materials, and 93% of these projects used UHPC for PBE connections.

Moving Beyond PBE Connections

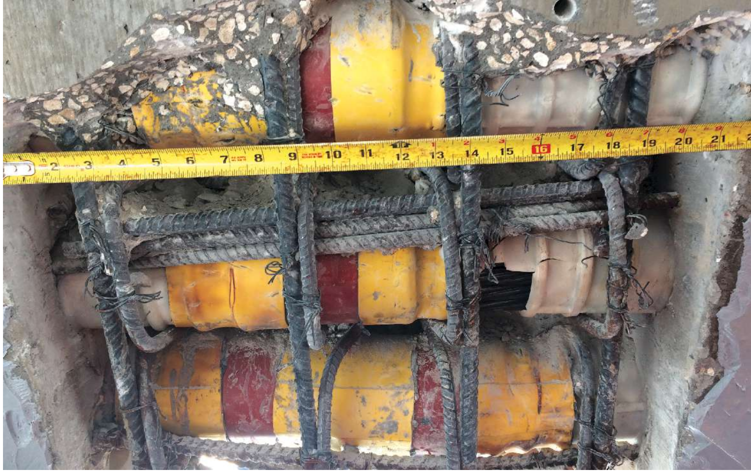
As UHPC-class materials become more prevalent, new and innovative applications for these materials in bridge design and construction will continue to emerge. One emerging application for UHPC in the U.S. highway bridge sector is for bridge repair, retrofit, and rehabilitation. Since 2016, at least 10 U.S. bridges have been repaired or rehabilitated using UHPC-class materials, and, for the most part, each application has had unique aspects. (Refer to the *FHWA Interactive UHPC Bridge Map* for additional details.[2])

Four of these projects (in Colorado, California, Florida, and Rhode Island) marked the first use of UHPC on state-owned highway bridges. Each of these projects used relatively small volumes of UHPC material and were viewed as relatively low risk by the bridge owners. As such, repair applications are becoming an alternative entry point for bridge owners looking to generate institutional knowledge and familiarize local

Ultra-high-performance concrete repair of connections between precast, prestressed concrete voided-slab beams in Florida. Photo: Florida Department of Transportation.



The first installation in the United States of an ultra-high-performance concrete bridge deck overlay was in Iowa. Photo: Federal Highway Administration.



Ultra-high-performance concrete was used for the repair of a midspan spliced U-girder closure pour. Photo: SEMA Construction Inc.

contractors with UHPC.

The following innovative UHPC-based repair solutions have been implemented, conceptualized, or laboratory tested:

- UHPC overlays for bridge deck rehabilitation
- Repair of existing connections between PBEs
- Structural patching of reinforced concrete bridge decks, prestressed concrete girders, and bearing pedestals
- Expansion joint repair with UHPC headers or replacement using UHPC link slabs
- Seismic retrofit of deficient bridge column-footing lap splices
- Structural strengthening of deteriorated girder ends

The first three of these applications are summarized here.

UHPC Overlays for Bridge Decks

In one of most promising UHPC-based bridge repair applications, UHPC is used as a thin, bonded overlay for bridge deck rehabilitation. As an overlay, UHPC can provide structural strengthening, protection from chloride and water ingress, and good resistance to mechanical abrasion, which reduces the tendency for rutting. This deck rehabilitation can be achieved with a 1- to 3-in.-thick layer of UHPC, which minimizes material volume and additional dead load. This repair method, which was pioneered in Europe, and has been deployed on more than 20 European bridges, is particularly competitive when an owner is looking to extend the life of a structure that is otherwise difficult to replace, such as a life-line structure, a historically significant bridge, or a structure in a challenging geographic or urban area. To date, there have been three UHPC overlays installed in the United States. The first of these installations was on a reinforced concrete slab bridge in an agricultural region in Iowa.[3,4] UHPC overlays are an active research topic at the Federal Highway Administration (FHWA) Turner-Fairbank Highway Research Center (TFHRC), and additional information can be found in references 3 through 6.

Repair of Existing Connections

UHPC-class materials are known to be excellent candidates for closure pours for PBE connections because these materials can provide durable connections and very compact reinforcement details.[1] The Florida Department of Transportation (FDOT) leveraged these characteristics to repair an existing bridge (constructed in 1978) with precast, prestressed concrete voided-slab beams. The units were transversely post-tensioned and employed partial-depth, conventionally grouted shear keys. After years of service, reflective cracking became apparent in the bridge's asphalt overlay, and there was evidence of differential deflection between adjacent slab units. Instead of replacing the superstructure, FDOT decided to remove the existing connection regions using hydrodemolition, install additional reinforcement, and replace the removed concrete with UHPC. Laboratory testing of similar connections using UHPC between adjacent box beams has demonstrated that UHPC has the ability to create full composite action and robust performance.[6]

Structural Patching and Localized Repairs

UHPC-class materials have been used for localized repair of expansion joint headers, structural patching of bridge decks, and structural patching of prestressed concrete bridge girders. An example of structural patching was performed on a recently constructed, multispan interstate flyover. This bridge had a spliced U-girder superstructure. During construction, poorly consolidated concrete was identified within a closure pour at a midspan girder-to-girder splice location. The poorly consolidated concrete was removed and replaced with UHPC. UHPC was selected as the repair material because it bonds very well with steel reinforcement and existing concrete, and because it is highly flowable and self-consolidating. The region to be repaired was highly congested; thus, the repair material needed to have excellent flow properties.

Moving Forward

The advancement of bridge repair and preservation practices using innovative materials such as UHPC is a current area of focus for research within the Structural Concrete Research Group at FHWA TFHRC. We are striving to develop new solutions to solve some of the continual challenges related to bridge preservation. We hope this article spurs innovative thinking as it relates to concrete bridge repair, and we look forward to assisting owners with the identification, design, and installation of innovative solutions.

References

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