



DEPLOYMENT OF ULTRA-HIGH-PERFORMANCE CONCRETE TECHNOLOGY

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The previous issue of *ASPIRE*[™] provided an overview of ultra-high-performance concrete (UHPC) and introduced the Federal Highway Administration's (FHWA)'s research and deployment efforts. This article expands the discussion to include the specific deployment efforts completed and those underway in the United States.

From the previous article, "UHPC refers to a class of exceptionally durable and strong cementitious composites, usually containing fiber reinforcement and exhibiting self-consolidating properties. UHPC has been used in Europe and Asia in building vehicular bridges, pedestrian bridges, and other types of structures."

The aging of highway bridges in combination with traffic congestion related issues has created a situation where the need for bridge owners to repair, replace, and construct durable bridges is greater than ever. There is a strong demand for new solutions to existing problems, and the advanced mechanical and durability properties of UHPC open many new avenues toward these solutions.

First Deployments

The Mars Hill Bridge in Wapello County, Iowa, was the first UHPC bridge on a public road in the United States. This three-girder bridge spans 108 ft and uses 42-in.-deep precast, prestressed UHPC girders. The Iowa Department of Transportation (IowaDOT) modified the girders from the standard Iowa bulb-tee design by using thinner flanges and narrower webs. The traditional shear reinforcement was also eliminated because testing at FHWA's Turner-Fairbank Highway Research Center and Iowa State University demonstrated that the UHPC,

with its steel-fiber reinforcement, was sufficient to resist the design loads. Among other things, this project demonstrated the viability of casting UHPC bridge girders in a conventional precast concrete plant. The bridge opened to traffic in 2006. More details of the Mars Hill Bridge are given in the Summer 2007 issue of *ASPIRE*.

A similar deployment was completed at the Cat Point Creek Bridge near Warsaw, Va., in 2008. This 82-ft-span bridge used 45-in.-deep prestressed concrete I girders. The Virginia Department of Transportation (VDOT) used their standard bulb-tee girder shape and, like the Mars Hill Bridge, eliminated the use of normal steel shear reinforcement. The five UHPC girders were included in the second span of this 10-span bridge.

Optimized Girder Deployment

The initial research and deployment of UHPC technology in the United States demonstrated the capabilities of the material and the feasibility of component fabrication for infrastructure projects. Moreover, these projects also demonstrated that the development of new, structurally optimized girder shapes is warranted if the mechanical and durability properties of UHPC are to be efficiently engaged in superstructure elements. FHWA initiated a research program aimed at developing a precast, prestressed deck bridge girder component applicable to typical U.S. highway bridges. The result of this project was the pi girder, a 33-in.-deep, deck-bulb-double-tee girder that can span up to 87 ft. This component facilitates the accelerated construction of durable infrastructure systems. The IowaDOT completed the first deployment of the pi

girder in a bridge near Aurora, Iowa. The Jakway Park Bridge used three abutted adjacent pi girders in its main span. It opened to traffic in 2008. More details of the Jakway Park Bridge are given in the Winter 2010 issue of *ASPIRE*.

Precast Deck Connections

The advanced mechanical properties of UHPC have also proven capable of advancing the state-of-the-art in bridge component connection technology. In recent decades there has been a push toward accelerating bridge construction through the use of precast components; however, joining these components in the field with durable, robust connections has sometimes proven problematic. The bond properties of UHPC have created an opportunity to re-engineer connections, especially at the deck level, in an effort to construct robust, simple, and durable details.

The New York State Department of Transportation is playing a leading role in using UHPC to create splice connections between deck-level components. During the summer of 2009, they constructed two bridges using this type of connection detail. The first bridge, located in Lyons, used UHPC to create the deck-level connection between adjacent deck-bulb-tee prestressed concrete girders. This 6-in.-wide connection across which the reinforcement is spliced, is filled with field-cast UHPC. More details are given in the Fall 2009 issue of *ASPIRE*. The second bridge used UHPC to connect together conventional precast concrete deck panels. Located near Oneonta, the deck panels were placed on steel stringers, then the extended reinforcement was spliced within a 6-in.-wide UHPC connection.



The Mars Hill Bridge near Ottumwa, Iowa, uses three 42-in.-deep UHPC girders modified from the standard Iowa bulb tee to span 108 ft. Photo: FHWA.



Adjacent deck bulb tees being aligned for level prior to field-casting a UHPC longitudinal joint on the State Route 31 Bridge over the Canandigua Outlet in Lyons, N.Y. Photo: New York State DOT.



The Cat Point Creek Bridge near Warsaw, Va., uses standard VDOT bulb-tee UHPC girders, 45 in. deep, spanning 85 ft. Photo: FHWA.

Concurrently, there is a research effort ongoing at FHWA that focuses on the mechanical and durability properties of these deck-level connection details. Results to date from cyclic structural loading of full-scale connections have demonstrated very good performance.

Bridge Re-decking System

The exceptional durability of UHPC also presents opportunities for directly addressing the pressing need for bridge deck replacements around the nation. An FHWA analytical study, combined with previous experience in the United States and abroad, has led to the development of a structurally optimized precast UHPC deck panel. The two-way ribbed panel (i.e., waffle panel) is approximately 30% lighter than a conventional concrete deck panel and is significantly more durable. Engaging the connection details discussed above allows for the accelerated construction of an all-UHPC deck.

This system is being put to the test currently in Iowa where a bridge will be constructed in the summer of 2010. Coreslab Structures Inc. of Omaha, Neb., received a Highways for LIFE grant to lead a project further developing this concept. They are working with the IowaDOT, Wapello County, Iowa State University, and Lafarge North America Inc., to test and deploy the concept. Fourteen waffle panels will be used to deck the 60-ft-long, 33-ft-wide bridge over Little Cedar Creek in Wapello County.

Conclusion

Advanced structural materials, such as UHPC, open doors to new structural systems and construction techniques that can assist in the rehabilitation and reconstruction of highway bridges. To date, UHPC has been deployed in five U.S. highway bridges, and additional deployments are planned. UHPC has been demonstrated as a viable alternative for both precast components and field-cast connections. As familiarity with UHPC increases, additional deployments of existing concepts and development of new concepts are anticipated. UHPC presents great opportunities to construct durable, resilient infrastructure systems.



Jakway Park Bridge near Aurora, Iowa, is the first project to use the optimized pi girder. It is 33 in. deep and spans 87 ft. Photo: FHWA.



State Route 23 over Otego Creek near Oneonta, N.Y., features conventional precast concrete deck panels with extended reinforcement spliced in 6-in.-wide connections using UHPC. Photo: FHWA.



A laboratory test deck panel like the ones being used for Little Cedar Creek Bridge in Wapello County, Iowa. Photo: Iowa State University.

EDITOR'S NOTE

The FHWA UHPC Research Program is managed by the Bridge Design and Construction Team at the Turner-Fairbank Highway Research Center in McLean, Va. Further information on research and deployment of UHPC technology can be obtained by contacting Dr. Graybeal at bgraybeal@dot.gov or 202-493-3122.