UHPC Bridge Implementations in North America since 2019

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Abstract

This presentation builds on previously shared information by this author during the First and Second International Interactive Symposia on UHPC in 2016 and 2019, respectively. It is meant to provide an overview of the ultra-high performance concrete (UHPC) bridge activities and projects in the recent years following the last symposium in 2019. As of the writing of this paper (March 2023), more than 500 bridge structures in North America have utilized UHPC in their construction, with applications ranging from closure pours between precast deck panels and beam modules, link slabs, expansion joint headers, steel beam encasements, and bridge deck overlays. A few of these projects will be discussed herein.

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1. Utilization in North America

UHPC utilizations in North America in the early years (prior to 2016) predominantly consisted of UHPC connections between precast deck panels/elements in New York state and Northwestern Ontario. From 2016 to 2019, we saw further expansion of this application into several surrounding states in the Northeast (e.g. Pennsylvania, New Jersey) and a few states out West (e.g. Idaho, California). Since 2019, an additional ten States have completed a first UHPC installation in their state, including Alabama, Arizona, Connecticut, Indiana, Maryland, Missouri, New Mexico, Oklahoma, Texas, and West Virginia. With these new States added, at least 39 of the 50 U.S. States (including Hawaii) have utilized UHPC in a bridge related application, bringing the total number of bridge structures with UHPC in North America in excess of 500 bridges, with the largest portion of those belonging to New York, Pennsylvania, New Jersey, Iowa, Idaho, and Florida.

2. Typical Applications

UHPC closure pours between precast concrete elements continue to be a popular application for this technology. The West Virginia Turnpike recently completed several Accelerated Bridge Construction (ABC) deck replacement projects along sections of Interstate 77 using multiple UHPC suppliers. The reception has been largely positive and the Turnpike continues to work with their Engineer of Record, HNTB, to utilize this design methodology on upcoming projects. Likewise, larger projects surrounding New York City continue to utilize these types of systems following the success of the Pulaski Skyway re-decking project and the Major Deegan Expressway rehabilitation. Recent multi-year projects in NYC include sections of Bruckner Expressway near Hunts Point and portions of the Van Wyck Expressway. In Washington D.C., the iconic Arlington Memorial Bridge underwent a deck replacement in 2020 using precast deck panels and UHPC connections, as did the Columbia River Bridge in The Dalles, Oregon in 2021-2023.

UHPC connections between prefabricated modules (e.g. voided slabs, box girders, decked bulk-tees, etc.) continue to gain in popularity as well. These types of modules are generally easier and faster to install, which can make them excellent options for Accelerated Bridge Construction scenarios, particularly when the superstructure elements warrant replacement as well. The IowaDOT recently completed a multi-bridge letting in which numerous single-span bridges in various counties throughout the state were replaced using prestressed concrete box beams w/ longitudinal UHPC connections. Other states have utilized similar bundling strategies to optimize UHPC installation efforts, such as Texas with a five bridge bundle in 2021, and the Brightline transit line in Florida who has completed multiple bridges throughout 2021 and 2022.

Link slabs, while originating in New York state (and continuing to be implemented there), continue to rise in popularity and are being implemented in more and more states and at a larger scale. Such is the case in Wheeling, West Virginia where a series of link slabs was installed along miles of Interstate 70 throughout 2020 to 2022. Similarly, in Wilmington, Delaware, a stretch of the Interstate 95 viaduct was rehabilitated with UHPC link slabs in 2021 and 2022. And in New Jersey, the Turnpike continues to construct UHPC link slabs into sections of their interstate highways.

A couple newer applications were recently completed as well. In Milford/Stratford, Connecticut, the existing steel grid deck of the Washington Bridge was replaced by a new light-weight decking system that utilized a semi-thixotropic UHPC infill placed into the pan of the decking assembly to improve the deck's rigidity and provide an impermeable layer for the new riding surface. The prefabricated decking was then installed on the bascule span and joined together onsite using field-cast UHPC closure pours. For a project in Los Angeles, California for the LA Metro, over 20 cubic yards of UHPC was mixed via ready-mix truck and pumped via a concrete boom pump to fill a large section of pier cap that will serve as a post-tensioning splicing region subjected to high compressive forces upon final structure configuration.

3. Bridge Deck Overlays

UHPC for bridge deck overlays is another application that is emerging quite rapidly. Only four bridges had implemented a UHPC bridge deck overlay between 2016 and 2018 in Iowa (the first adopter) and Delaware. Since 2019, the interest has grown appreciably, partly due to the success of these early adopters and also due the Every Day Counts (EDC-6) initiative deployed by the U.S. Federal Highway Administration (FHWA) to raise awareness about this durable and viable solution. New York State has since installed a UHPC overlay on more than six bridges throughout the state and New Jersey has completed four bridges of their own as part of two research contracts. A small test overlay has also been installed at the BEAST at Rutgers where large-scale testing is ongoing. Additionally, New Hampshire, Illinois, and Oklahoma have also completed their first overlay projects, with Iowa adding to their tally as well.

Owners of larger bridges have started to explore and experiment with this solution as well, most notably the Delaware Memorial Bridge (DMB) in Delaware/New Jersey, the Commodore Barry Bridge in Pennsylvania/New Jersey, and the Newport Pell Bridge in Rhode Island. Of these three 2020 pilot installations, the DRBA (owner of the DMB) has since begun a mega-project to fully rehabilitate the entire 2-mile (3.2-km) long Northbound bridge deck by removal of the top 2-in (50-mm) of contaminated cover concrete via hydrodemolition and then installation of an equivalent thickness of thixotropic UHPC overlay material, followed by grinding and grooving of the final, impervious riding surface. Phase 1 of 3 (consisting of 25% of total work) was completed in Fall 2022 with more than 1,100 cubic yards (840 cubic meters) of UHPC installed over >15,000 sq. yards (12,500 sq. meters) of deck area. Phases 2 and 3 will occur in Q1/Q2 and Q3/Q4 of 2023, respectively, concluding the remaining 50% and 25% of installation work, respectively.

4. Mixing Equipment

It is well known that UHPCs generally require high-shear mixing equipment in order to efficiently mix the material to its fluid or plastic state. Hence, vertical shaft, horizontal single-shaft, horizontal twin-shaft, or planetary style mixers (of various sizes) are often employed to mix this material onsite or in a plant setting. However, in recent years, there has been a more notable desire to utilize traditional ready-mix trucks for mixing the UHPC, where practical, of which some UHPC suppliers have been doing so for several years now.

A ready-mix truck can offer several advantages including 1) a larger payload of UHPC, e.g. 6 cubic yards (4.6 cubic meters), ready to place all at once (e.g. for pumping), 2) the ability to utilize local mixing equipment without the need for an external power source (e.g. a generator), and 3) the potential cost savings associated with not having to mobilize mixing equipment to a jobsite that may otherwise not be readily available nearby.

5. Codes and Standards

The North American industry continues to work on technical literature and design practices for implementing UHPC. Since 2019, the following documents have been published, or are known to be in progress, and may be of use in further implementing the above mentioned applications. Note that several of these documents are now allowing UHPCs to be classified with a compressive strength less than 21.7 ksi (150 MPa) at 28 days, e.g. >18 ksi (124 MPa) at 28 days.

1. CSA A23.1:19, Annex U Ultra-High Performance Concrete (UHPC), 2019
2. FHWA-HRT-19-011, Design and Construction of Field-Cast UHPC Connections v2, 2019
3. TR-9-22, Guidelines for the Use of Ultra-High Performance Concrete (UHPC) in Precast and Prestressed Concrete, 2022
4. FHWA-HRT-22-065, Design and Construction of UHPC-Based Bridge Preservation and Repair Solutions, 2022
5. FHWA-HRT-23-012, Ultra-High Performance Concrete (UHPC) Overlays: An Example of Lifecycle Cost Analysis, 2022
6. AASHTO T397 Standard Method of Test for Uniaxial Tensile Response of Ultra-High Performance Concrete, 2022
7. AASHTO Guide to Preservation of Highway Bridge Decks, 2023
8. AASHTO LRFD Guide Specification for UHPC, in progress
9. ACI 239-C Guide on the Structural Design of UHPC, in progress
10. ACI 239-D Guide on Materials and Methods of Construction for UHPC, in progress