

Project Description:

Ultra-high performance concrete (UHPC) is the next generation of concrete, a concrete whose mechanical and durability properties far exceed those of conventional concretes. UHPC combines together a set of advancements in concrete technology from recent decades to create a concrete with compressive strengths at or greater than approximately 20 ksi, sustained post-cracking tensile strength at or greater than 750 psi, and a discontinuous pore structure that reduces permeability by an order of magnitude. During the past 10 years, UHPC has found significant usage in the US bridge sector as a field-cast grout cast between prefabricated bridge elements; effectively, UHPC enabled novel accelerated bridge construction methods to flourish. As the awareness of UHPC capabilities as grown, interest has turned toward using UHPC for primary structural elements in bridges. The handful of primary structural component deployments in the US so far (e.g., a few pretensioned girders, a few precast bridge decks, a few piles) have been completed as experimental deployments by innovative departments of transportation. Mainstreaming of this technology will require a broader knowledge base and greater standardization of engineering practices. Researchers at the FHWA Turner-Fairbank Highway Research Center have been leaders in advancing UHPC technology for the bridge sector for nearly two decades. The proposed project will allow them to broaden the scope of their efforts and thus provide more substantial input to the AASHTO community as formal guidance for the design of UHPC components is developed. The objective of the TPF project is to develop knowledge pertinent to the structural performance of UHPC. This knowledge will be of significant value as the AASHTO Committee on Bridges and Structures considers the use of UHPC-class materials in highway bridges and structures. The proposed project is focused on the design, fabrication, performance, and analysis of UHPC components. It is anticipated that various UHPC components will be designed, fabricated, and tested. The test results will be analyzed and used to inform proposed structural design guidance for UHPC components. Results will also be used to support usage of UHPC by interested departments of transportation. It is anticipated that bridge superstructure components (e.g., pretensioned girders) will be a significant part of this study, with behaviors related to flexure, shear, and end zones being investigated. Other components may be investigated based on available resources and the interest of participating partners.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

- FHWA Report FHWA-HRT-23-077 *Structural Design with UHPC* was published. It includes the draft UHPC structural design recommendations that were developed by FHWA and provided to AASHTO for their consideration. It also includes two examples highlighting the analysis of a rectangular mild steel reinforced UHPC beam and the design of a pretensioned UHPC I-Beam with a conventional concrete deck.
- *AASHTO Guide Specification for Structural Design with Ultra-High Performance Concrete*
 - The FHWA team continued to develop and refine the draft UHPC Materials Conformance Guidance that will parallel the UHPC Structural Design Guide Specification. AASHTO's Concrete Structures Committee held two working meetings wherein the draft guidance related to UHPC material qualification requirements and quality control testing processes was discussed.
- Fatigue Behavior of UHPC Beams.
 - Continued to work on investigating the tensile fatigue behavior of UHPC beams with the goal of refining the fatigue provisions proposed in the UHPC Guide Spec draft. The research team is conducting fatigue tests on existing large-scale UHPC girders that remained from a previous testing program that focused on UHPC prestressed girder behavior under static shear or flexure loading. The experimental work will subject the untested portions of the prestressed girders to repetitive cycles of loads and document any degradations in strength and stiffness as compared to those observed in the static testing of these girders.
 - Cyclic testing of the second test specimen has progressed with 25 million cycles having been completed by the end of the reporting period. This pretensioned girder had previously been subjected to cracking in the web and is being cycled under a simulated truck loading to investigate cracked UHPC fatigue performance.
- Development Length of Prestressing Strands in UHPC
 - The testing of the final 6 pretensioned beams, each containing 3 strands, was initiated.
- Flexural Behavior of Heavily Reinforced UHPC
 - A suite of beams has been fabricated and currently are awaiting test at FHWA-TFHRC. Precursor material testing has begun.
- UHPC Materials Conformance Testing
 - An extensive research project investigating tensile and compressive mechanical test methods for UHPC conformance testing is being initiated. It is anticipated that the testing will include AASHTO T 397, ASTM

C1609, modified versions of ASTM C1609, Florida DOT Double Punch Test, and ASTM C1856 (compression and modulus of elasticity). The results will help inform the development of the UHPC Materials Conformance Guidance.

Anticipated work next quarter:

- Continue to support AASHTO Committee on Bridges and Structures (CBS) Concrete Structures Committee as they evaluate the FHWA proposed draft UHPC Materials Conformance Guidance.
- Continue work on a journal paper draft detailing the results of the experimental investigation utilizing servo-hydraulic and non-servo hydraulic loading frames in performing direct tension tests of UHPC specimens in accordance with AASHTO T 397.
- Continue work on the UHPC tensile fatigue behavior project: continue cycling second girder.
- Continue testing of 12 pretensioned beams that were designed to investigate the development length of prestressing strands.

Significant Results:

- The AASHTO *Guide Specification on Structural Design with UHPC* is almost entirely based on the content that FHWA's team developed for their consideration. The document was successfully balloted by AASHTO on May 25, 2023.
- An FHWA report covering the technical content of the draft AASHTO Guide Spec on Structural Design with UHPC as well as two structural analysis and design examples was published in October 2023.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

The study team is actively engaging the nine contributing State DOTs to solicit their feedback and to ensure that the results are applicable. In short, the study team is partnering with the contributors to continually adjust the direction of the project into the most beneficial direction. It is anticipated that this method of project scoping and management will ensure that the project results are implementable by at least many of the contributing DOTs.