TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): FHWA

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *TPF-5(468)*	**Transportation Pooled Fund Program - Report Period:** ☐Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☒Quarter 4 (October 1 – December 31)

Project Title: Structural Behavior of Ultra-High Performance Concrete		
Name of Project Manager(s): Ben Graybeal	**Phone Number:** 202-493-3122	**E-Mail:** benjamin.graybeal@dot.gov
Lead Agency Project ID: TPF-5(468)	**Other Project ID (i.e., contract #):** n/a	**Project Start Date:** January 2021
Original Project End Date: December 2025	**Current Project End Date:** December 2025	**Number of Extensions:** 0

Project schedule status:

☒ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$800,000	$160,000	20%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
$40,000 and 5%	$40,000	5%

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.):

- Continued to support AASHTO Committee on Bridges and Structures (CBS) subcommittee T-10 on Structural Concrete to evaluate FHWA proposed draft of an “AASHTO Guide Specification for Structural Design with Ultra-High Performance Concrete” for possible adoption.
    - The research team at FHWA responded to all comments received by December 1, 2021. The research team continues to receive comments from members and is working on addressing them.
    - A new version of the proposed draft, i.e. v1.1, was delivered to AASHTO CBS T-10 on December 14, 2021. The new version includes editorial corrections and other updates that the research team identified and/or members of AASHTO CBS T-10 suggested.
- Developed two design/analysis examples implementing various design concepts included in the proposed UHPC Guide draft and shared it with AASHTO CBS T-10 members on December 14, 2021. The examples cover the design of a pretensioned UHPC I-beam bridge with conventional concrete deck and the analysis of a rectangular, mild steel reinforced UHPC beam.
- Continued to support the efforts of AASHTO Committee on Materials and Pavements (COMP) to publish a “Standard Method of Test for Uniaxial Tensile Response of Ultra-High Performance Concrete”. The test method was originally drafted by the FHWA research team and was then raised to the attention of AASHTO COMP Subcommittee TS3c. After passing the ballot at the level of the AASHTO COMP main committee, the research team at FHWA began supporting AASHTO production team to publish the new standard method of test. When published in a few months, the standard will be AASHTO T 397.
- Continued the development of visual aids to assist users in performing the soon-to-be-published AASHTO T 397 “Standard Method of Test for Uniaxial Tensile Response of Ultra-High Performance Concrete”.
- Completed a direct tension experimental study to compare the test results obtained from specimens tested in servo-hydraulic and non-servo-hydraulic loading frames; the results verified the applicability of non-servo-hydraulic operated loading frames in performing direct tension tests of UHPC specimens in accordance with AASHTO T 397. The research team is working on publishing the work in the form of a journal paper.

- Executed the first experimental test in the research project focused on prestressing strand development length in UHPC. The results verified the test method for evaluating the development length of various strand diameters in UHPC-class materials and provided a reference for efficiently conducting future tests.
- Worked on evaluating the tensile stress-strain relationship of UHPC based on ASTM C1609 "Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)". Investigating pitfalls and misconceptions that can arise from inappropriately interpreting the results of flexural tests to obtain the key tensile parameters. These parameters are critical to the appropriate design of UHPC structural members. The research team is exploring an experimental program to highlight these issues.
- Started a research project investigation focused on 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 developing a work plan to conduct fatigue tests on existing large-scale UHPC girders that remained from a previous testing program which focused on UHPC prestressed girder behavior under static shear or flexure loading. The planned experimental work will subject the untested portions of the prestressed girders to repetitive cycles of load and document any degradations in strength and stiffness as compared to those observed in the static testing of these girders.

Anticipated work next quarter:

- Work on developing version 1.2 of the "AASHTO Guide Specification for Structural Design with Ultra-High Performance Concrete" based on comments received from the members of AASHTO CBS T-10 and other interested parties. Deliver the draft to AASHTO CBS T-10 by February 1, 2022.
- Work on developing version 1.1 of the two design/analysis examples and deliver to AASHTO CBS T-10 by February 1, 2022.
- Continue to work on the parametric study to investigate the effects of various input material, geometrical, and design characteristics on UHPC bridge girder behavior and the development of design aids for designing UHPC bridges. The study aims to provide designers with support to enable the appropriate use of UHPC's improved material behaviors in the design of highway bridges.
- Execute experimental tests on the remaining initial test specimens for the prestressing strand development length project. The results will be used to launch Phase II of the project with the goal to assess the impact of multiple parameters on the development length of prestressing strands embedded in UHPC.
- Finalize the work plan for the fatigue testing of UHPC girders, prepare the test specimens for testing, erect the test setup, calibrate the instrumentations, and run the first test.

Significant Results:

- Developed a new version, i.e. v1.1, FHWA proposed draft of an "AASHTO Guide Specification for Structural Design with Ultra-High Performance Concrete" and shared with AASHTO CBS T-10.
- Developed two design/analysis examples implementing the various design concepts included in the proposed UHPC Guide Specification draft.
- The "Standard Method of Test for Uniaxial Tensile Response of Ultra-High Performance Concrete" has passed AASHTO COMP main committee and is now in production for publication as AASHTO T 397.
- Completed a direct tension experimental study that verified the applicability of non-servo-hydraulic operated loading frames in performing the direct tension tests of UHPC specimens in accordance with AASHTO T 397.
- Executed the first experimental test on the initial test specimens for the prestressing strand development length project; the results verified the test method for evaluating the development length of various strand diameters in UHPC-class materials and provided a reference for further improvement.

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 in 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.