EXPLORING FIBER-REINFORCED POLYMER CONCRETE FOR ACCELERATED BRIDGE CONSTRUCTION APPLICATIONS

Quarterly Progress Report
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1. Background and Introduction

The use of precast concrete superstructure elements is a popular strategy for accelerated bridge construction (ABC) and rehabilitation projects. The major advantage is that precast concrete elements can be fabricated before, or in parallel with, on-site activities, thus expediting project delivery. To complete the superstructure, closure joints between adjacent precast superstructure elements are filled with a field-cast material, creating continuity between the concrete elements and splicing steel reinforcement that protrudes from the precast members into the joints. The geometry of the closure joints, the speed at which the connections can be completed, how long before the bridge can be opened to traffic, and the cost of the system are all dependent on the material that is used to fill the gaps between precast elements. The closure joint material must possess strength and durability equal to or better than the adjacent concrete and must be capable of transferring the tensile forces between reinforcement from adjacent elements.

2. Problem Statement

The tension and bond strengths of ultra-high performance concrete (UHPC) make it an excellent closure joint material. However, the time at which UHPC achieves its design strength is directly proportional to the rate of hydration of the cementitious binder. While UHPC may provide the best solution in many instances, alternative joint materials that utilize polymer binders, instead of cementitious ones, may be more suitable if rapid strength gain is needed. This project explores a potential alternative closure joint material, fiber-reinforced polymer concrete (FRPC), which displays levels of the two critical characteristics (bond and tension strength) that are comparable to, or potentially better than, those of UHPC. FRPC has the advantage of requiring shorter closure windows (approximately 4 hours versus 72 hours of UHPC) due to the very rapid strength gain of the polymer, which could be ideal for overnight construction or rehabilitation projects, and provides an additional option to the engineer and contractor when choosing a closure joint material for a particular circumstance.

3. Objectives and Research Approach

The objectives of the proposed research are to review the most promising FRPC materials, assess the temperature dependent properties of FRPC behavior, characterize the mechanical properties (tensile, flexural, and compressive strength) of cast FRPC, and characterize the splice performance of deformed bars embedded in FRPC materials. Based on the results of this experimental investigation, recommendations for the use of FRPC in ABC applications will be developed to maximize the benefit of this relatively new material for different ABC project applications.

4. Description of Research Project Tasks

The following is a description of tasks carried out to date.

Task 1 – Literature Review

This task is complete. Previous research on fiber reinforced polymer concrete has been compiled and separated into areas of interest pertinent to bridge construction applications. A summary of the compiled research can be found in the September 2021 Progress Report.

Task 2 – FRPC Material Characterization

This task is complete. The mechanical properties of a commercially available FRPC material, Kwik Bond Hybrid Composite Synthetic Concrete (HCSC), were determined at several test temperatures and ages using standard test methods that would be part of a typical quality control program (i.e. compressive strength, tension strength, and anchorage strength). An overview of the results can be found in the December 2021 Progress Report.

Figure 1 shows the elastic modulus of HCSC as a function of time and temperature. A new piece of instrumentation became available this reporting period and supplementary data investigating the elastic modulus was collected. In general, the plots follow similar trends to the compression, flexure, and bond strengths presented previously. As seen in the figure, the compressive modulus of HCSC is lower than cementitious concrete (UHPC or high-strength concrete) at room temperature.

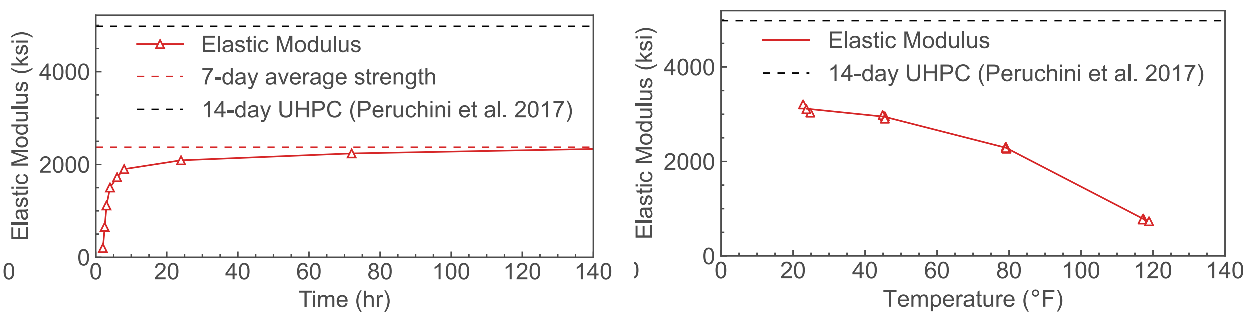

Figure 1 Elastic modulus as a function of time and as a function of testing temperature

Figure 2 shows the complete stress-strain relationship for HCSC at different ages and temperatures, established under displacement control at a rate of 0.05 in/min. The stress strain curves for the cylinders tested at 5 °F were limited by the capacity of the universal testing machine. The strengths and elastic moduli were both somewhat lower (between 5-10%) than those obtained under load control, loaded at 20 to 50 psi/sec consistent with ASTM C39 [ASTM 2021].

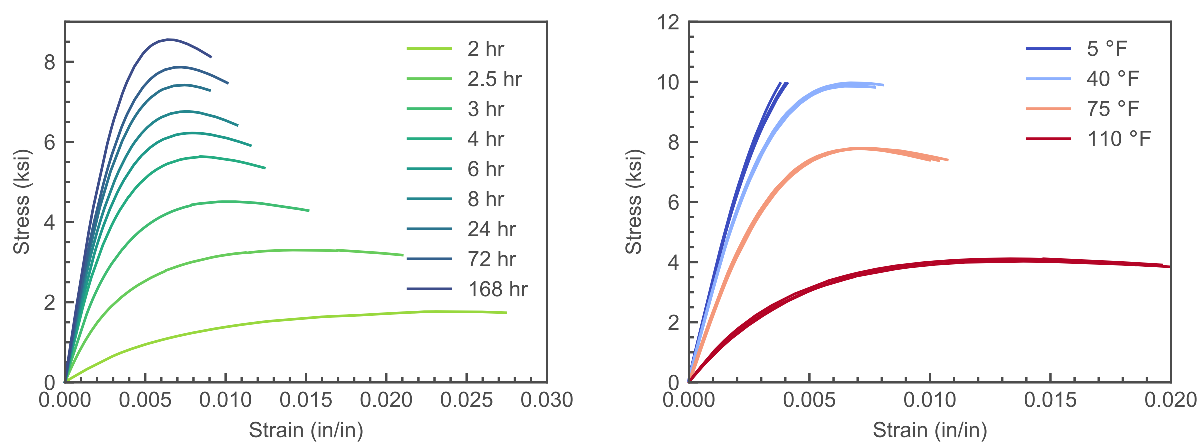

Figure 2 Compressive stress-strain behavior as a function of time and temperature (5 °F curve limited by the capacity of the testing machine).

Task 3 – Testing of Splice Specimens

This task is complete. The tests investigated a simplified, non-contact splice configuration that isolates the behavior of reinforcement in a closure joint. The specimen size was selected to allow conditioning the specimens to different temperatures using conventional laboratory equipment and tested using a universal testing machine under precise displacement control. The variables that were investigated include the temperature at time of testing, overlap length between bars, side cover, and bar size. Additional details of the testing plan and the experimental results can be found in the March 2022 Progress Report and June 2022 Progress Report, respectively.

Task 4 – Development of Design Recommendations

This task in complete. The *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction* (AASHTO 2018) recommends a minimum embedment length for deformed bar reinforcement in UHPC, l_d, of $8d_b$ for #8 bars or smaller with f_y less than or equal to 75 ksi and clear cover greater than or equal to $3d_b$. The splice length for straight deformed steel reinforcement is recommended to be at least $0.75l_d$. The results of the non-contact splice tests support using HCSC in closure joints with identical geometries as those recommended for UHPC for service temperatures in the range of 0-110 °F. The capability of HCSC to permit the same joint geometry as UHPC would help increase the potential closure pour options for a given ABC project, especially when rapid strength gain is beneficial. Additional details of the testing plan and the experimental results can be found in the August 2022 Progress Report.

Task 5 – Interim and Final Reporting

This task in ongoing. The research team will submit timely quarterly reports, present annually at the Research Days meeting, and complete a final report summarizing findings reached during the project.

Writing for the final report is nearly complete. It will be finalized and submitted in the next reporting period.

5. Expected Results and Specific Deliverables

The successful completion of the research project will directly impact the design/construction industry, by providing a better understanding of the properties of FRPC and its potential for use in closure joints between precast members, such as decked bulb tees, PCI NEXT beams, or precast deck panels. The main deliverable will be a report that summarizes:

- Recommendations for the selection of FRPC as a closure joint material in ABC applications,
- Design equations for the required development length of epoxy coated reinforcement embedded in FRPC, and
- Example closure joint geometry utilizing FRPC.

In addition, the results of the project will be summarized in a 5-min demonstration video and a journal publication.

6. Schedule

Progress on tasks in this project is shown in the tables below.

Item	% Completed
Percentage of Completion of this project to Date	95%

Research Tasks	2021											2022												2023	
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Task 1 – Literature Review																									
Task 2 – FRPC Material Characterization																									
Task 3 – Testing of Splice Specimens																									
Task 4 – Development of Design Recommendations																									
Task 5 – Interim and Final Reporting																									

7. References

American Association of State Highway and Transportation Officials. 2018. AASHTO LRFD guide specifications for accelerated bridge construction. Washington, DC. AASHTO

Garber, D., and E. Shahrokhinasab. 2019. “ABC-UTC Guide for: Full-Depth Precast Concrete (FDPC) Deck Panels.”

Graybeal, B. 2014. Bond Behavior of Reinforcing Steel in Ultra-High Performance Concrete. Washington, D.C.: USDOT FHWA.

Minitab. 2022. “Getting Started with Minitab Statistical Software.”

Peruchini, T. J., J. Stanton, and P. Calvi. 2017. Investigation of Ultra-High Performance Concrete for Longitudinal Joints in Deck Bulb Tee Bridge Girders. 213. Olympia, WA: Washington State Department of Transportation.