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Project Title

Durability and Volumetric Stability of Non-Proprietary Ultra High Performance Concrete Mixes Batched With Locally Sourced Materials

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Research Needs

Ultra High Performance Concrete (UHPC) has received widespread attention for its ability to outperform traditional concrete in nearly every aspect. Due to its superior performance, the application of UHPC does not follow the traditional rules and expectations of standard cementitious materials. According to the FHWA definition, the material must exhibit a compressive strength greater than 20 ksi and a post-cracking tensile strength greater than 0.72 ksi to be classified as UHPC [1]. Additionally, UHPC has a discontinuous pore structure that increases durability by reducing liquid ingress and UHPC enables the development of reinforcing steel in inches rather than feet.

So far, commercial premixes, such as Ductal®, CEMTEC multi-scale, and CERACEM have dominated the construction industry when it comes to UHPC applications. These premixes have been reported to have a compressive strength over 29 ksi, a bending strength over 3.15 ksi, and a Young's modulus over 7.25 ksi [2, 3, 4]. Although the performance of these UHPC proprietary mixes is exceptional, they are very expensive. A summary of commercially available UHPC by [5] reports that the price of UHPC varies from \$1,956/yd^3 to \$3,718/yd^3.

To counter this high cost, a significant amount of research has been performed on materials classified as UHPC, including non-proprietary mix designs developed by transportation agencies in other regions. Non-proprietary mix designs developed using locally available materials can result in significant cost savings by eliminating the need to purchase expensive proprietary UHPC mixes from specialized commercial suppliers. The first step toward having a useable non-proprietary product by employing local materials is the development of its mix design and ensuring that the non-proprietary UHPC mix demonstrates satisfactory quality. A common feature of UHPC application in the field is the small volume of the material that is produced. This is also due to the high cost associated with purchasing proprietary UHPC from the supplier and the cost of specially trained contractors and workers. An optimized non-proprietary UHPC mix without fibers developed for the Michigan Department of Transportation costs $513/yd^3. Every 1% increase in steel fiber content by volume increases the cost by approximately $516/yd^3 [6]. A locally developed non-fiber UHPC for Colorado Department of Transportation costs $1,535/yd^3 [7].

Recently the PI received funding from the Utah Department of Transportation (UDOT) to develop a specification for a UHPC mixture using materials readily available in the Salt Lake City area. The objectives of that research focus on material analysis, compressive strength, and workability (the ability to place in the field is of specific interest). However, these properties are only part of what makes a successful and useable UHPC mix. The research proposed herein is to also examine the durability and volume stability of a locally sourced mix design. These two items are of specific interest to UDOT as the typical application of UHPC is for bridge closure pours.

Research Objectives

The objective of this research project is to determine the durability and volumetric stability of a non-proprietary UHPC mix batched with materials commonly available in the Salt Lake City, Utah area. The specific properties to be evaluated for durability are freeze-thaw and chloride ion penetration. The properties to be assessed for volumetric stability are length change and autogenous shrinkage.

Research Methods

The objectives of this research will be attained by separating the project into discrete tasks as outlined below.

Task 1: Literature review. Existing information in previous studies on the durability and volume stability of non-proprietary UHPC mixes will be gathered. Of particular interest in this task is identifying those mix characteristics that have the most effect on the durability and volumetric stability of UHPC.

Task 2: Experimental testing. The UDOT study proposes the parametric evaluation of a number of different iterations of the mix designs. Once a promising mix design is obtained, the results of the work in Task 1 will be utilized to undertake a parametric study of mix characteristics and their impact on durability and volumetric stability. The specific tests to be carried out are:

1. Freeze-thaw durability according to ASTM C666
2. Chloride-Ion penetration according to AASHTO T358

3. Length change according to ASTM C157
4. Autogenous Shrinkage according to ASTM C1698

For each test, three to five variations of the control mix design are anticipated to be evaluated.

Task 3: Final Report. A final report will document the results of Tasks 1 and 2 with an emphasis on reporting practical implications to decision makers in the transportation sector. The results of this study will be included with the results of the UDOT study to develop a standard for non-proprietary UHPC mixes.

Expected Outcomes

The outcome of this project will result in a non-proprietary UHPC mix sourced with locally available materials for UDOT projects. In addition to the mechanical properties such as compressive strength and modulus of elasticity, this project will ensure that these mix designs are also durable and have limited volumetric change. This will result in a higher performing material for UDOT that not only saves money, but performs as needed for the service life of the structure.

Relevance to Strategic Goals

This project directly relates to the USDOT strategic goal of Economic Competitiveness. The development of a non-proprietary UHPC mix for UDOT will decrease construction costs associated with the usage of UHPC and will also allow for UHPC to be more widely used. As previously discussed in this proposal, non-proprietary UHPC mixes have shown to be at least 50% less expensive than proprietary mixes.

Educational Benefits

The majority of the research work on this project will be carried out by a dedicated Ph.D. level graduate student with assistance from other students in the PI's research group and under the PI's supervision. Students will gain invaluable experience in carrying out physical experiments on an advanced material. It is anticipated that the students will also present the results of the research at national conferences.

Technology Transfer

The results of this research will be published in peer-reviewed technical publications as well as presented at conferences. Additionally, the findings will be used to prepare a UDOT standard for the design and placement of non-proprietary UHPC mixes with locally sourced materials.

Work Plan

The proposed research will be carried out over a 12-month period with time allotted to each task item identified in the Research Methods section of this proposal as follows:

- Task 1: 2 months
- Task 2: 8 months
- Task 3: 2 months

Project Cost

Total Project Costs:	$150,000
MPC Funds Requested:	$ 75,000
Matching Funds:	$ 75,000
Source of Matching Funds:	Utah Department of Transportation

References

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