ABC-UTC 2015

Quarterly Report

A. PROJECT TITLE: Investigation of Macro-Defect Free Concrete for ABC including Robotic Construction

B. START & END DATE: 10/1/2015-9/30/2017

C. PI & Co-PI(s): Brent Phares

D. PROPOSAL ABSTRACT: (Not to exceed 300 words)

A major construction equipment manufacturer had developed several formulations of a so-called macro-defect free concrete. This material is unlike any cement-based material currently available. In fact, the material is much more closely related to various types of rubber – although with vastly different properties than rubber. Although initial basic material property testing has been promising, there is a significant lack in knowledge of what exactly it “is” and what it “isn’t”. The goal of the project will be to assess important material characteristics and to develop conceptual uses for the material with a specific focus on accelerated/robotic bridge construction.

E. DESCRIPTION OF RESEARCH PROJECT

E.1. PROBLEM STATEMENT

Accelerated Bridge Construction (ABC) has grown by leaps and bounds over the past several years. Some of those advances have been driven, at least in part, by the maturation of newer materials that have properties conductive to working in an ABC environment An emerging material developed by a major construction equipment

manufacturer offers the possibility to be the “next great thing” in ABC. However although some basic material tests have been performed there is a significant void in understanding what the material is capable of and what it isn’t capable of. This project will be the first step in determining whether or not macro-defect concrete can be used in innovative ABC projects. The material, known in many contexts as macro-defect free concrete has several possible attributes that may make it desirable for ABC projects include: high strength (comparable to Ultra-high performance concrete), rapid early strength, extremely low permeability, and the ability to be extruded on-site to fit specific project needs. However with a full suite of material characterization tests coupled with strategic, engineering-based assessment, the full potential (or lack thereof) cannot be realized. This research hopes to answer some of the questions regarding the potential for using macro defect free concrete in ABC projects.

E.2. CONTRIBUTION TO EXPANDING USE OF ABC IN PRACTICE

There exists a great opportunity to expand the materials available for use in ABC projects. If viable, macro-defect free concrete could represent a revolutionary ABC development.

E.3. RESEARCH APPROACH AND METHODS

To accomplish this work a comprehensive set of material characterization tests will be performed. Once a full understanding of the material characteristics has been realized, the research team will develop conceptual ways in which the material could be used in an ABC environment.

E.4. DESCRIPTION OF TASKS TO BE COMPLETED IN RESEARCH PROJECT

The conduct of this synthesis will be performed in accordance to the following general tasks. The current status of each task is also included.

Task 1 – Literature review including the discovery of material with characteristics similar to macro-defect free concrete.

A traditional literature review will be conducted to identify research related to macro defect free concrete and its applications. Further, literature on the use of extruding technologies for the on-site construction of civil assets will be identified and reviewed.

The literature review has largely been completed. Macro defect free (MDF) concrete was developed in the early 1980's and has been improved upon in the decades since. Macro defect free concrete has properties similar to those of ceramics, plastics and metals and are typically created via the high shear mixing of polymers and hydraulic cements at low w/c ratios. Traditional limitations of MDF have included low moisture resistance, shrinkage and difficulty processing on a commercial scale. Recently, a large manufacturing company (Caterpillar) made great strides in addressing these limitations via the creation of Cemposit. This material overcomes moisture resistance issues and its possible infrastructure applications served as the motivation behind this study.

Task 2 – Material characterization including the conduct of compressive, tensile, permeability, durability, and other standard tests.

During Task 2, a full suite of material characterization tests will be conducted. Initially, the plan calls for testing compressive strength, tensile strength, permeability, freeze-thaw

durability, as well as others. Although macro defect free concrete does not appear, at least initially, to have a strong time-dependency associated with the development of these properties, conventional testing approaches and methodologies will be followed to allow for direct comparison with traditional and non-traditional materials.

To date, we have worked with the material manufacturer to perform an initial series of compression and tensile tests to investigate how fabrication impacts these engineering parameters. Following initial test result analysis, a second iteration of the mix matrix was developed. Although there were several motivations for this, the primary motivation was to increase the ductility of the matrix.

In addition, a site visit was conducted to better understand the material and its manufacturing process. This visit was in December and allowed for further discussion of subsequent testing iterations. While fibers were added to the material to improve upon the toughness behavior, the amount of fibers required to achieve these characteristics are impractical and greatly impacted the mixability of the material. This site visit and discussion of material behavior were critical for the work associated with Task 3 to be completed.

Task 3 – Concept development including the development of means and methods of using macro defect free concrete in ABC projects.

With a greater understanding of the capabilities of macro defect free concrete, the research team will convene at least one working group meeting to brainstorm ideas for using macro defect free concrete in civil infrastructure with a strong emphasis on ABC. Subsequently, the research team will further develop any potentially viable ideas into

more mature concepts. Where appropriate, the research team will conduct both structural and economic analyses of the concepts.

Task 4 – Reporting.

E.5. EXPECTED RESULTS AND SPECIFIC DELIVERABLES

The expected result is a full understanding of the material characterizes and potential uses of macro defect free concrete in bridge applications. This work will also result in a description of additional research work needed which would ultimately result in the construction of a bridge using macro defect free concrete.

E.6. TIMELINE

This work is expected to be completed in an approximately 2 year period.

F. DISCUSSION OF PERTINENT COMPLETED AND IN PROGRESS RESEARCH. FOR PROJECTS CO-FUNDED BY OTHER SOURCES, COPY OF THE CO-FUNDED PROPOSAL SHOULD BE ATTACHED AS AN APPENDIX.

A brief literature search did not reveal any documents related to the use of macro defect free concrete in bridges.

G. DESCRIBE THE PLAN FOR COOPERATING WITH OTHER ABC-UTC CONSOURTIUM UNIVERSITY MEMBERS

As part of this work the research team will form a Technical Advisory Committee (TAC) to oversee and guide the work. Each of the other ABC-UTC consortium members will be asked to nominate a member to serve on the TAC. The TAC for this project shall meet at least once per quarter (to be scheduled in advance) such that the research team can provide regular and timely updates on project status, problems, and results.

Additionally, each of the consortium members will be invited to nominate a faculty member to serve on the graduate research assistant's Program of Study (POS) committee as a non-voting member. In these two capacities the consortium members will play direct and important roles in multiple aspects of the research.

Additionally, the research team will work closely with researchers at FIU on efforts related to robotic bridge construction. Macro defect free may offer opportunities for merging with robotic construction methodologies due to the fact that the material can be extruded on site to meet exact site conditions. At this time it is anticipated that the ISU/FIU researchers will work collaboratively in the following ways"

1. Monthly check-in calls to discuss progress and planned activities.
2. Sharing of test results as they become available.
3. The conduct of a one half day brainstorming session between key contributors at both universities. It is likely that this brainstorming session will occur virtually or in person at a mutually attended national conference..

H. KEY WORDS

Macro defect free concrete, ABC.

I. LITERATURE CITIED

J. STAFFING PLAN (Should correspond with budget)

This work will be conducted under the guidance of Dr. Brent Phares.