Development of Novel Ultra-High Performance Engineered Cementitious Composites (UHP-ECC) for Durable and Resilient Transportation Infrastructure

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$135,000

Developing an effective infrastructure composite to increase durability of concrete structures

In structural design, strength and ductility of structural materials are of utmost importance in ensuring safety and reliability, especially in extreme conditions. As such, imbuing concrete with high strength and ductility capabilities could possibly allow for the design of civil infrastructure with concrete as the solo structural material. Recently, UltraHigh-Performance Engineered Cementitious Composites (UHP-ECC) have been proposed to overcome the limited ductility of Ultra-High-Performance Fiber-Reinforced Concrete (UHP-FRC) and produce cementitious composites with outstanding mechanical properties. The design of this emerging class of concrete materials is based on the combination of the micromechanics and fracture mechanics design concepts of ECC and the high particle packing density matrix design approach of UHPC. Combining both grants both high strength and high ductility. The objective of this project is to develop novel UHPECC materials utilizing readily available ingredients in Region 6. Developing such materials will provide the region with the latest cementitious composites for the construction and repair of transportation infrastructure as well as for further research and development.

Problem Statement

Concrete materials display two well-known weaknesses: low tensile strength and highly brittle nature. As such, concrete materials have steel reinforcement to produce sound structural members ensuring sufficient tensile load carrying capacity, safety, and reliability. While steel reinforcement is central to the structural performance of reinforced-concrete elements, steel rebar is the root cause of reinforced concrete structures deterioration due to corrosion (Figure 4a). In turn, steel rebar considerably limits the durability potential of modern infrastructure. For example, Roman buildings such as the Pantheon (built without steel reinforcement) are still standing after almost two thousand years (Figure 4b); yet, modern reinforced concrete structures have a hard time exhibiting a durability of one hundred years or greater. The durability problem of modern infrastructure is a critical challenge to be solved by researchers over the next decades. A potential countermeasure is to provide new concrete materials exhibiting high tensile strength and ductility which can eliminate the need for rebar. As such, rebar-free structures could eliminate the corrosion deterioration and allow for far better durability. Additionally, the absence of steel reinforcement could lead to a major increase in construction productivity as the rebar placement activity (which is very time-consuming) would no longer be required. Moreover, such a material would be perfect for use with emerging construction techniques like 3-D printing where steel reinforcement impossible.

Objectives

This research project aims to develop novel Ultra-High-Performance Engineered Cementitious Composites (UHP-ECC) materials with readily available ingredients in Region 6. The development of such materials will provide the region with the best cementitious composites available for the construction and repair of transportation infrastructure as well as for further research and development. UHP-ECC implementation can significantly improve durability, resiliency, and structural safety of the infrastructure in the region by providing a more reliable material alternative directly serving the following objectives:

- Objective 1: Prolong existing transportation infrastructure life by applying emerging technologies in materials and construction.
- Objective 2: Promote sustainability and flexiibiity of the transportation infrastructure renewal and upgrade.
- Objective 3: Introduce and implement economical countermeasures to the transportation infrastructure backlog of projects.

- Objective 4: Develop cost-effective solutions for the construction and maintenance of the transportation infrastructure in urban and rural areas

Intended Implementation of Research

Education and Workforce Development: This study will fund one PhD student at Louisiana State University. This will help recruit and train future leaders in the Transportation Sector specializing in developing new materials for transportation infrastructure. The research team will also prepare educational material on UHP-ECCs to be incorporated in courses at LSU and share it with other universities. The educational material will also be summarized and disseminated to government entities and the industry. Results of this work will be also disseminated at national conferences such as TRB and ASCE.

Outreach: This project offers two internships for undergraduate students to introduce them to research in Transportation and Advanced Materials. Furthermore, the developed educational material will be shared with our partner community colleges to recruit students to Transportation. In addition, educational information explaining findings of the project will be offered to research institutes and companies interested in emerging innovative technologies for the Transportation Sector in collaboration with the highway agencies in Region 6.

Figure 1: Ductile Behavior of ECC Material Developed at LSU

Anticipated Impacts/Benefits of Implementation

The main deliverables from this study are: (1) final report will be prepared including the problem description, objective, scope, methodology, results, conclusions, and recommendations and (2) Research results will be shared at national TRB and ASCE conferences.

Web links

- Tran-SET's website https://transet.lsu.edu/research-in-progress/

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.