Engineered Geopolymer Composites (EGC) for Sustainable Transportation Infrastructure

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$90,000

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Tran-SET
Louisiana State University
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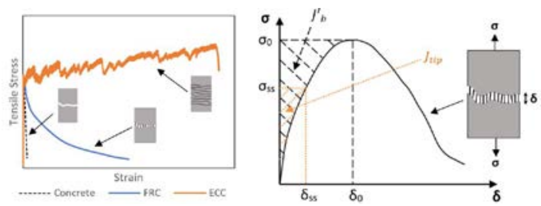
$270,011

Developing novel Engineered Geopolymer Composites (EGCs) implementing locally available ingredients

The objective of this study is to develop novel Engineered Geopolymer Composites (EGCs) implementing locally available ingredients to produce a new generation of materials that are practical, cost-effective, and eco-friendly for repair and new construction of transportation infrastructure in the South-Central region. In order to achieve this objective, EGC mixtures will be designed with different types and proportions of locally available precursor materials (mainly locally available fly ash and metakaolin). EGCs fresh and hardened properties will be evaluated to identify key parameters ensuring EGC strain hardening response as well as optimum design of the composition balancing fresh and hardened properties. Furthermore, bonding properties of EGC with regular concrete will be assessed. Finally, a cost analysis for EGC implementation will be performed by comparing the cost of EGC materials to current materials utilized in the field.

Problem Statement

Concrete has proven itself through time as an outstanding construction material; yet, it is not elusive to well documented weaknesses. Concrete is brittle and possess a low tensile strength. Adding fibers to concrete is a well-established practice to mitigate the brittle behavior of concrete by limiting crack growth and propagation. Yet, traditional fiber reinforced concrete (FRC) produces rather marginal improvements in ductility and tensile strength. Furthermore, FRC continues to exhibit a strain-softening phenomenon after first cracking under tensile stresses as shown in Figure **1**. For these reason, high performance fiber reinforced cementitious composites (HPFRCC) were developed as a superior alternative to mitigate concrete brittleness and its weak behavior under tensile stresses. In contrast to FRC, HPRFRCC exhibit a strainhardening performance after first cracking under tensile stresses. Strain-hardening occurs due to inelastic deformation of the composite through the formation of multiple micro-cracks.



(a) (b)

Figure 1. (a) Stress vs. Strain Behavior of Cementitious Materials in Tension (b) Fiber Bridging Relation (σ-δ Curve).

This inelastic deformation takes place with an increase in load carrying capacity and is referred as pseudo strain-hardening (PSH) to differentiate this mechanism with the strain-hardening phenomena observed in metals. Early versions of HPFRCC were designed by utilizing high contents of fiber (4-20% volume fraction) and achieved desirable improvements in tensile strength and ductility. However, high fiber contents limited its application in the field due to constructability issues and cost. ECCs are a new class of high-performance fiber reinforced cementitious composites (HPFRCC), which are designed and optimized based on micromechanical principles. In contrast to traditional HPFRCC, ECCs can exhibit a high tensile ductility 2 to 5% strain capacity in tension**.**

An emerging class of strain-hardening fiber reinforced composites are Engineered Geopolymer Composites (EGCs). EGCs are designed and optimized based on same micromechanical principles utilized in the conception of Engineered Cementitious Composites (ECCs) to exhibit robust PSH behavior at low fiber content. Some initial studies suggests that like ECCs, EGCs exhibit high tensile ductility and an enhanced tensile and flexural strength compared to typical fiber reinforced concrete. Yet, due to the relative low fracture toughness of geopolymer matrices, high tensile ductility of EGCs can be achieved at lower fiber content than in ECCs. Thus, offering potential cost savings and increased practicality.

Due to its superior mechanical properties, greenness, and cost-effectiveness potential, EGCs are proposed as a novel alternative material for repair and new construction of transportation infrastructure.

Objectives

The objective of this study is to develop novel Engineered Geopolymer Composite (EGC) materials implementing locally available ingredients to produce practical and cost-effective EGCs for repair and new construction of transportation infrastructure in the region.

Intended Implementation of Research

Education and Workforce Development: This research project will provide funding to one PhD student at Louisiana State University and one graduate student at Texas A&M University. This will help recruit and train future leaders in the Transportation Sector specializing in development of new materials for transportation infrastructure. The research team will also prepare educational material on EGCs to be incorporated in courses at LSU and TAMU 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 will offer two internships for undergraduate students to introduce them to research in Transportation and Advanced Materials. Moreover, the developed educational material prepared in this project will be shared with our partner community colleges to be used to recruit students to Transportation. We anticipate to use demonstration material in multiple K-12 outreach activates traditionally carried out by Women in Materials Science (WiMS) student organization at Texas A&M University. In addition, educational information explaining findings on 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.

Anticipated Impacts/Benefits of Implementation

The development of EGC materials implementing local ingredients will deliver cost-effective and environmentally friendly high-performance materials for new construction and repair of transportation infrastructure in the region. EGC implementation has the potential for significant improvements in durability, resiliency, and structural safety of the infrastructure in the region by providing with a more durable and reliable material alternative directly serving the following objectives of the Center:

Objective 1: Extend the life of the existing transportation infrastructure through the application of emerging technologies in materials and construction.

Objective 2: Promote sustainability and resiliency of the transportation infrastructure renewal and upgrade.

Objective 3: Introduce and implement cost-effective solutions to the transportation infrastructure backlog of projects.

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

Objective 5: Enhance the resiliency the transportation infrastructure in the event of extreme weather events.

Web Links

- TranSET's website (https://transet.lsu.edu/research-in-progress/)
- TRB's Research in Progress (RIP) database (https://rip.trb.org/View/1642178)

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 our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Mr. Christopher Melson (Tran-SET Program Manager) directly at transet@lsu.edu.