Evaluation of the Performance and Cost-Effectiveness of Engineered Cementitious Composites (ECC) Produced from Region 6 Local Materials

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Optimizing engineered cementitious composites (ECCs) for potential field implementation

The objective of this project is to produce cost-effective ECC materials with Region 6 local available materials. To fulfill this purpose,several ECC mix designs will be produced with different proportions of locally available materials. ECC mixes fresh and hardened properties will be evaluated including slump flow, tensile strength, flexural strength, compressive strength, strain hardening performance and steady-state crack width. Properties will be evaluated to identify key parameters ensuring ECC strain hardening response as well as optimum mix designs balancing fresh and hardened properties. Finally, a feasibility study for ECC implementation will be performed by comparing the lifecycle cost of ECC materials as compared to current materials utilized in the field.

Problem Statement

Per the ASCE 2017 Report Card for America's Infrastructure, bridge deterioration is a significant issue in South Central States as most states within this region are under the national average grade of C+ which is already an inadequate grade (Table 1).

Table 1. Region 6 Bridges Grade (Per ASCE 2017 Report Card).

State	Bridges
US Average	C+
Louisiana	D+
Oklahoma	D+
New Mexico	C-
Arkansas	C+
Texas	B

Moreover, it has been estimated that almost half of concrete repairs in the and field fail consequently the cost of repeated repairs over the service life of a structure can be several times greater than that of the design and construction of a project.

In contrast with traditional concrete, ECC is a highly ductile cementitious composite material with intrinsic thigh crack width (usually below 100 µm) that produces an excellent concrete cover for reinforced concrete structures. Furthermore, several characteristics of ECC make it a suitable material for repair applications. For instance, ECC's superior ductility can absorb interface incompatibilities between the ECC/concrete repaired system eliminating spalling and premature delamination. Moreover, ECCs possess a significantly higher fatigue resistance as compared to commonly utilized repair materials such as polymer mortar. Specifically, in overlay repair applications primarily relevant to the transportation sector, delamination of concrete bridge overlays from substrate deck is one of the leading causes of ultimate overlay failure, which could be addressed by the implementation of ECC materials.

For this reason, the implementation of ECC is presented as an innovative solution to address durability problems of current and future infrastructure in the region. ECCs have the potential to be successfully implemented as a more reliable repair alternative as well as for new construction, providing structures with a superior service life compared to structures repaired and build under current practices.

Summary

The main goal of this study is to develop and characterize cost-effective ECC materials implementing locally available ingredients by:

- Developing ECC mix designs implementing locally available materials;
- Evaluating ECC mix designs mechanical properties;
- Characterizing ECC cracks;
- Identifying key parameters affecting ECC properties;
- Performing a feasibility study for field implementation.

This study is focused on the development of cost-effective Engineered Cementitious Composites (ECC) mix designs with locally available materials in Region 6 to address the deficiencies observed in ordinary concrete materials. The outcome of this study will determine the optimal ECC mix designs that balance performance, crack control, and cost.

Findings

Fresh properties: Fineness of sand as well as Fly Ash content were identified as important factors affecting workability and fiber dispersion on fresh ECC mixes. Finer sand produced better fiber dispersion as well as reduced bleeding (likely due to a more continue particle size distribution). Meanwhile, increasing contents of Fly Ash improved the workability of ECC mixtures (likely due to the sphericity of fly ash particles which favors workability).

Mechanical Properties: The compressive strength of ECC mixtures evaluated was significantly affected by the fly ash content in the mixes.Higher fly ash contents caused a decrease in strength. Yet, flexural, and tensile test results demonstrated that the increase in fly ash content was in favor of multiple cracking and strain hardening (likely due to the decrease in strength and crack-tip toughness of the cementitious matrix). Therefore, a trade-off between strength and ductility was observed. Moreover, a similar trend was observed when adding crumb rubber to the ECC mixes.Ductility of the composite increased, however, strength was reduced (particularly compressive strength). Strain hardening performance was observed in all mixtures evaluated. The strain hardening behavior of the ECC mixes during the flexural test is presented in Figures 1 and 2.

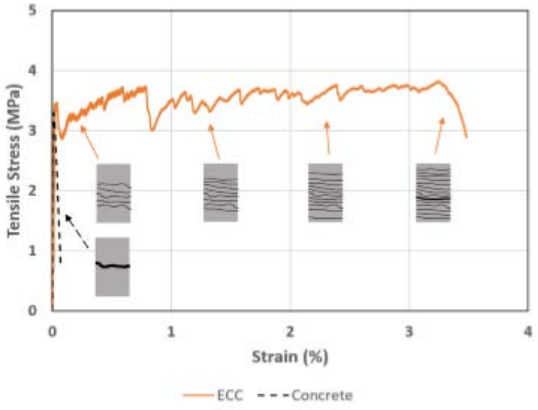

Figure 1. Strain-Hardening Process of ECC in Direct Tension.

Figure 2. ECC during a Flexural Test.

Impacts

The development of ECC with local materials will deliver cost-effective ECC mix designs that will be readily available for application in local infrastructure and further development of this innovative material in Region 6. ECC 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 alternative material for repair of current infrastructure and construction of new projects.

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".

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