UTC Spotlight

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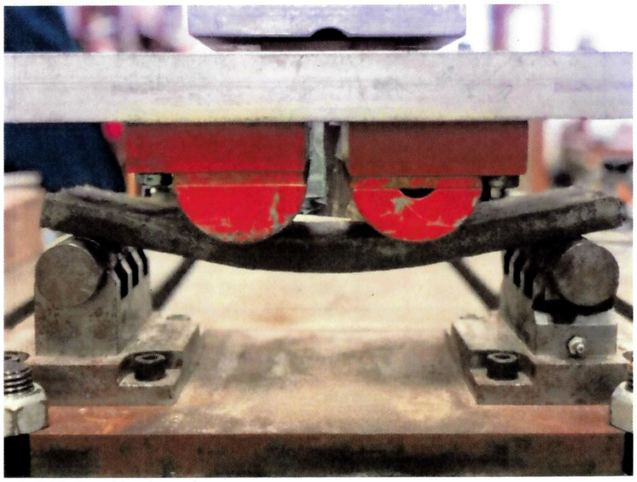
Louisiana State University with consortium members Arkansas State University, Baton Rouge Community College, Navajo Technical University, New Mexico State University, Oklahoma State University, Prairie View A&M University, Texas A&M University, University of New Mexico, University of Texas at Arlington, University of Texas at San Antonio

No. 121

Cost-Effective ECC for Transportation Infrastructure

The Transportation Consortium of South-Central States (Tran-SET) is a collaborative partnership between nine major institutions and two community colleges, led by Louisiana State University (LSU). Tran-SET's mission is to support all phases of research, technology transfer, workforce development, and outreach activities of emerging technologies that can solve transportation challenges in Federal Region 6. Tran-SET's research specifically focuses on improving the durability and extending the life of transportation infrastructure, and Engineered Cementitious Composites (ECCs) fit into the focus of Tran-SET as a material with the potential to significantly enhance the durability of current and future transportation infrastructure in the region.



Gabriel Arce

Figure 1: Highly Ductile ECC Material Developed at Louisiana State University

ECCs, also known as ductile or bendable concrete, are a special type of high performance fiber-reinforced cementitious composites, that are micromechanically designed to exhibit metal-like ductility at relatively low fiber content (Figure 1). In contrast to traditional concrete, ECCs can undergo substantial amounts of deformation -- 100 to 500 times that of regular concrete in tension -- through a controlled process of multiple micro-cracking called "pseudo strain-hardening." Because of their unique properties, ECCs have been proposed as a superior material for repair and construction of transportation infrastructure. For instance, ECC's exceptional ductility has the potential to mitigate reflective cracking in concrete overlays, eliminate the need for joints in rigid pavements (reducing repair and construction costs), and prevent brittle fracture due to repeated loading. The formation of small cracks (usually less than 60 μm) in ECCs provides these materials with enhanced durability in contrast to localized macro-cracks in traditional concrete or fiber-reinforced concrete. The small cracks limit the ingress of water and other detrimental substances into the structure, and allow the material to heal itself through autogenous healing phenomena of concrete materials.

ECCs are relatively novel materials that were first developed by Dr. Victor Li in the early 90s. Since then, ECCs have been perfected and thoroughly studied, yet mass adoption of these exceptional materials has been hindered by their high cost relative to conventional concrete. Two component materials of ECCs contribute to that higher cost: micro-silica sand and PVA micro-fibers (greatest impact), which are used at a 2% volume fraction. The Tran-SET-sponsored project, "Evaluation of the Performance and Cost-Effectiveness of Engineered Cementitious Composites (ECC) Produced from Region 6 Local Materials," took on this challenge by focusing on the development of ECC's using local, readily available ingredients, such as fine river sand, and examining the tradeoff between cost and ductile performance when fiber content is reduced. As a result of this work, ECC mixes with a variety of locally available ingredients and different types and contents of fiber are being developed and evaluated (Figure 2). The outcome of the project will be a spectrum of ECC mix designs at several levels of cost and performance.

At LSU, our research team aims to accelerate the implementation of ductile concrete in the region's transportation infrastructure by developing cost-effective ECC

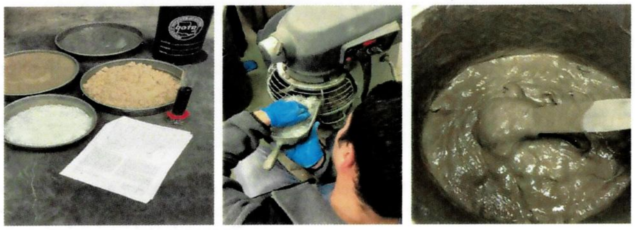


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Figure 2: ECC Production at LSU Implementing Local Ingredients

alternatives that utilize readily available ingredients and deliver robust and superior performance. Moreover, significant efforts are being made to incorporate local industrial by-products and waste materials - such as fly ash and crumb rubber - into ECC mix designs while maintaining satisfactory performance. The goal is to reduce the environmental footprint of the materials produced, and to achieve sustainable development.

To date, a more cost-effective, moderate-ductility ECC material has been successfully produced that utilizes fine river sand, achieves 62 percent cement replacement with locally available class F fly ash, and reduced fiber content (compared to typical ECCs) by 12.5 percent. The performance of the prepared ECC mix is promising, too: it exhibits a compressive strength higher than that of regular concrete (35 MPa), more than two times its flexural strength (Figure 3), and 180 times its tensile ductility (Figure 4) after 28 days of curing.

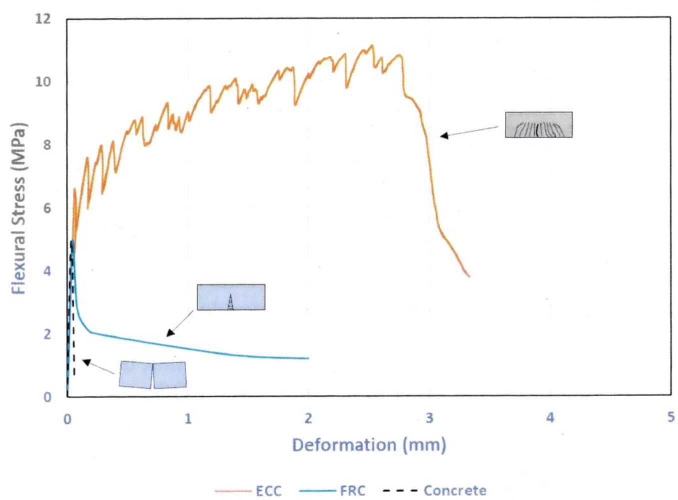

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Figure 3: Flexural Performance of Moderate Ductility ECC, Fiber Reinforced Concrete (FRC) and Concrete (100 x 100 x 350 mm beams according to ASTM C1609).

The implications of fostering widespread use of even moderate ductility ECCs in pavement design are profound. Typical fiber-reinforced concrete (FRC) has shown to be beneficial to the performance of slabs on the ground by increasing the flexural capacity of the slab. This increase in flexural capacity is attributed to increased toughness and residual strength provided to concrete by the addition of fibers (as measurable by ASTM C1609). The increase in flexural performance of FRC usually translates into the design of thinner and more durable pavements.

As shown in Figure 3, the toughness (area under the curve) of the moderate ductility ECC material developed at LSU is exceedingly superior to that of typical FRC. Moreover, ECC materials exhibit an increase in strength after cracking, rather than a residual strength. This remarkable outperformance of FRC opens a world of possibilities for ECCs in reduced-thickness pavement design, jointless design and superior durability. These dramatic manufacturing and performance breakthroughs could translate into important cost-savings in the transportation infrastructure in the region.

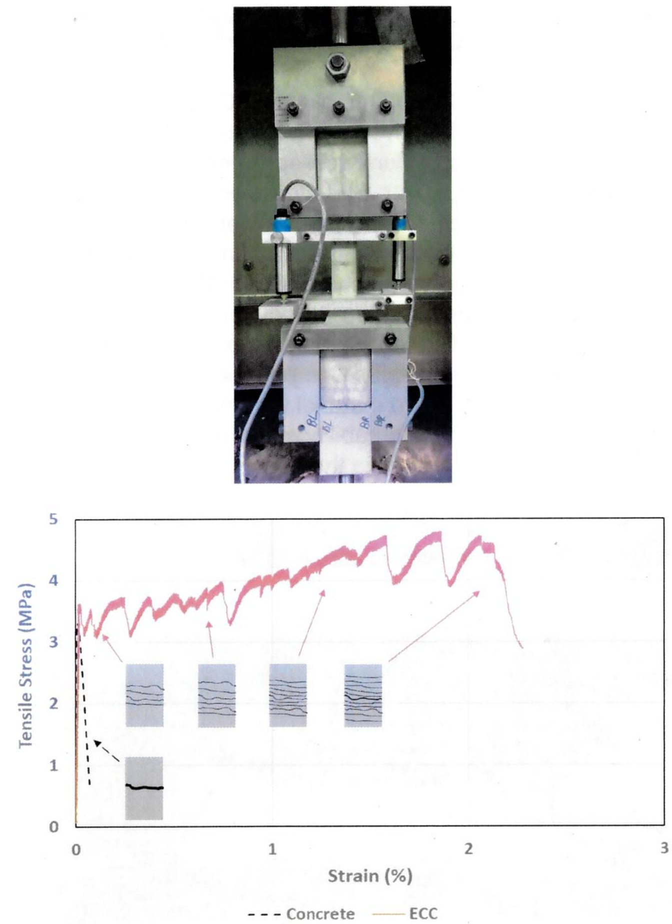

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Figure 4: Tensile Properties Evaluation of Moderate Ductility ECC by Uniaxial Tensile Test.

About This Project

The project "Evaluation of the Performance and Cost-Effectiveness of Engineered Cementitious Composites (ECC) Produced from Region 6 Local Materials" is led by Trans-SET Research Associate, Dr. Gabriel Arce. Dr. Marwa Hassan and Dr. Tyson Rupnow are Co-Principal Investigators. Dr. Hassan is the director of Tran-SET UTC and the CETF Distinguished Professor at the Department of Construction Management at Louisiana State University. Dr. Rupnow is the Associate Director at Louisiana Transportation Research Center (LTRC). For additional information, please send inquiries to garcea1@lsu.edu, marwa@lsu.edu or tyson.rupnow@la.gov.