Crack-free Ductile Concrete for Resilient and Sustainable Infrastructure

Advanced Construction Material for the 21st Century Infrastructure

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Motivation

Conventional Concrete lacks:

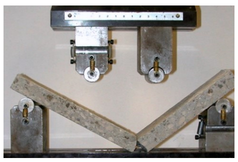

I90 Truck Crash (2005) → *Resilience*

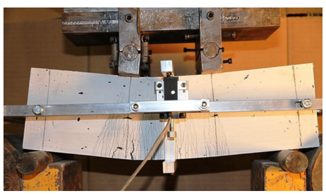

Spalling Due to Corroded Rebar → *Durability*


0.9 ton CO_2/ton of cement → *Sustainability*

Objective

To develop **crack free ductile concrete** for Resilient, Durable and Sustainable Infrastructure.


Brittle Concrete


Ductile Concrete (SHCC/ ECC)

Relevance to Transportation Infrastructure

- Vast network of roads and bridges transport 75% of goods nationwide accounting for over 30% of US GDP [Lepech et al 2005]
- FHWA estimates 200,000 bridges structurally deficient; estimating $20.5 Billion annually for next 16 years to update existing bridges [NACE: Highways and Bridges]
- One highway fire is reported every 182 second [NFPA 2012], causing $1.2 Billion direct property loss [NFPA 2016]
- Nearly 43 Megatons of cement used in USA for construction, repair and rehabilitation of concrete pavements annually [Lepech et al 2005]

Emerging SHCC Infrastructure


Bridge Pier


Expansion Joint

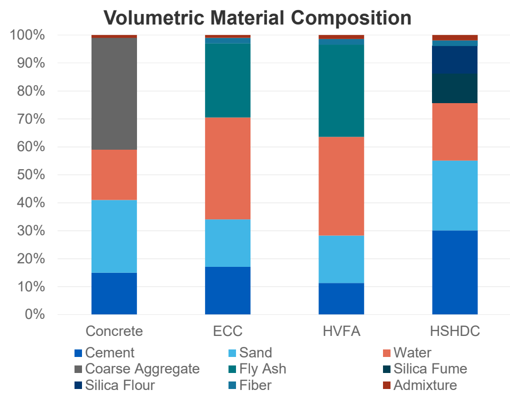

Tunnel


Precast Bridge Deck Connections


Pavement Overlays

Materials Research @ UB

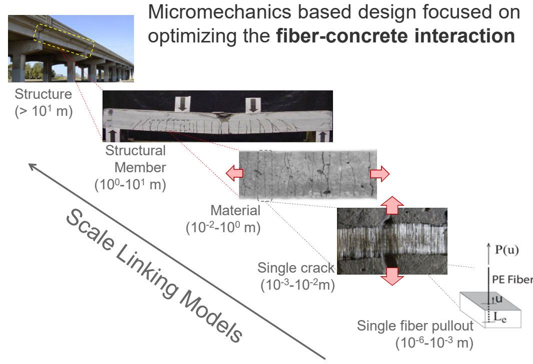
- We are developing macro crack-free ductile fiber-reinforced concretes known as: Engineered Cementitious Composites (ECC)
- Under tension, these concretes exhibit tensile-strain hardening similar to steel forming only tiny micro-cracks (< 60 μm)



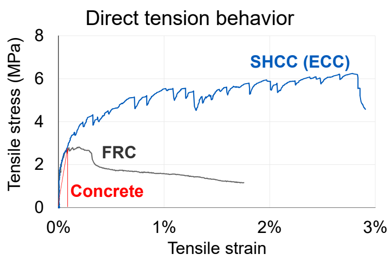
ECC – Engineering Cementitious Composite
HVFA – High Volume Fly Ash ECC
HSHDC – High Strength High Ductility Composite

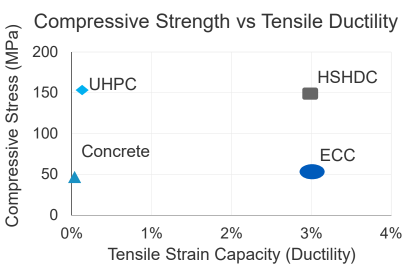
Research Approach

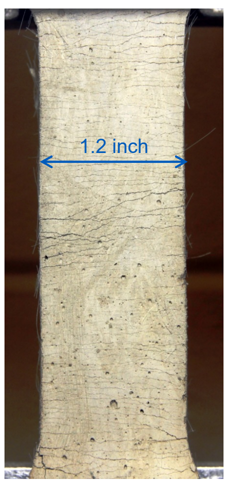
Micromechanics based design focused on optimizing the **fiber-concrete interaction**



Performance of Materials







Multiple cracking under uniaxial tension

Summary

- SHCC exhibits tensile strain capacity of about 3-5% while carrying increasing stress (strain-hardening) beyond the elastic limit
- Fibers in SHCC tightly control the crack openings keeping them under 60 μm
- Extremely fine cracks limit penetration of deleterious agents in post-elastic stage making ECC damage tolerant and extremely durable
- Life Cycle Analysis (LCA) of SHCC infrastructure shows lower Global Warming Potential (GWP) and Life Cycle Costs compared to conventional concrete

Paving the way for Future Infrastructure

- Self Healing SHCC: Reducing repair work
- Self Sensing SHCC: A step towards Smart Structures