Development of green and durable fiber reinforced geopolymer for truly sustainable infrastructure applications

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Introduction

Truly sustainable materials should be both green and durable. Geopolymer (GP), a completely cementless binder material, shows great promise as an green alternative to high energy/carbon intensive Ordinary Portland Cement (OPC). However, the commercial use has to date been limited mainly because of the inherent brittleness and corresponding low durability. On the other hand, Engineered Cementitious Composite (ECC), a ultra-ductile fiber reinforced composite, has highly increased the durability of OPC by enhancing ductility. The objective of this research is to develop durable fiber reinforced geopolymer composites for truly sustainable infrastructure systems.

Methods and Materials

Micromechanical Modeling

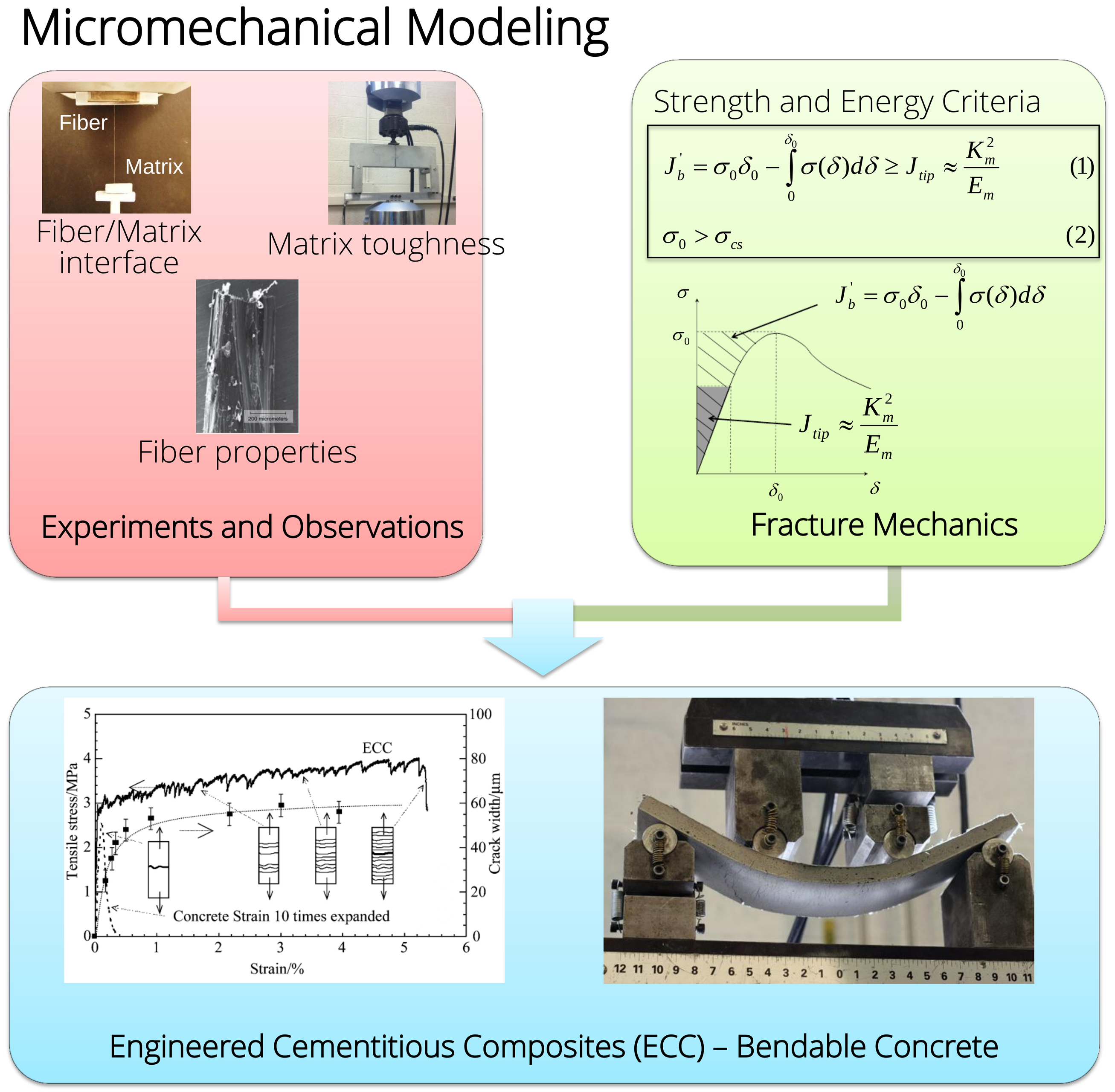

Figure 1. Micromechanics design of ultra-ductile fiber reinforced cementitious composites

- Micro-mechanical modeling is a powerful tool developed at the Univ. of Michigan to efficiently design ultra-ductile Engineered Cementitious Composite (ECC) materials, with tensile strain capacity over 3 %.
- Based on fracture mechanics & carefully designed experiments, optimal fiber, matrix and fiber/matrix interface properties are identified.

Experimental Investigation

- Geopolymer is made from fly ash activated by alkaline solution. Fly ash is a major industrial byproduct generated by coal-fired power plants.
- Based on micromechanical modeling, polyvinyl alcohol (PVA) fiber with the volume fraction of 2 % is added to geopolymer matrix.
- Casted specimens are cured in air at room temperature for 28 days.
- Direct uniaxial tension test is conducted on the developed fiber reinforced geopolymer composites to evaluate the ductility.

Figure 2. Direct uniaxial tension test on fiber reinforced geopolymer

Table 1. Mix proportions by weight

Fly ash	Sand	Water	NaOH-Na_2SiO_3 solution	PVA fiber volume %
1.0	0.3	0.12	0.35	2.0

Results

- The average tensile strain capacity of 4 specimens is 2.72 %, which is more than 250 times that of normal concrete.
- Tensile strain-hardening behavior can be clearly seen.
- Multiple crack propagations and tiny crack width are observed, which are unique characteristics of ECC leading to enhanced durability.

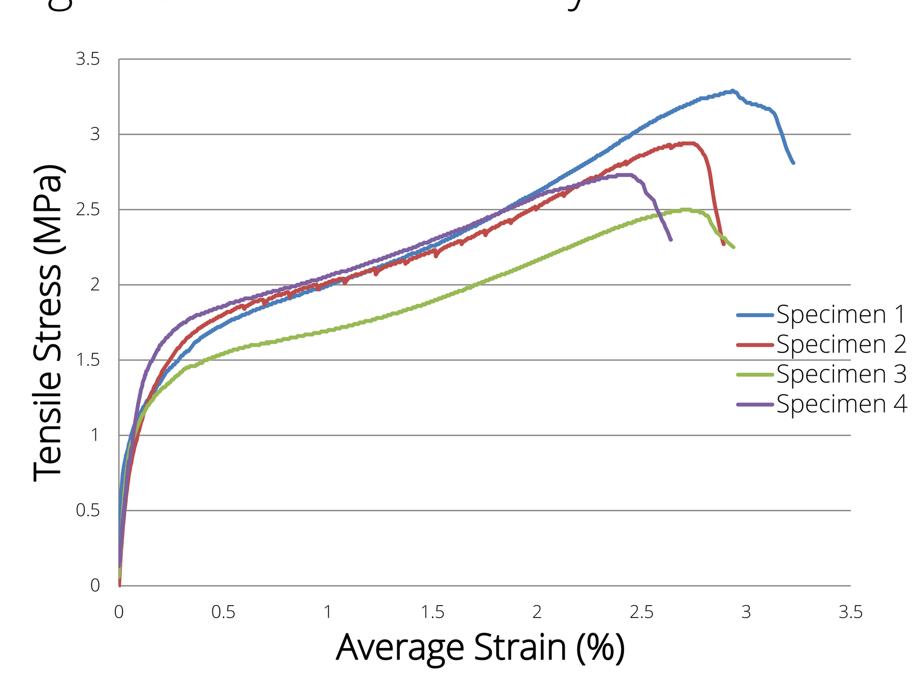

Figure 3. Tensile stress-strain behavior of fiber reinforced geopolymer

- The ultimate tensile strength is 2.87 MPa, which is almost the same as that of normal concrete.
- The compressive strength is relatively low, but applicable to various construction applications.

Table 2. Properties of fiber reinforced geopolymer and normal concrete

Property	Fiber reinforced geopolymer	Normal concrete
Compressive strength (MPa)	17.4	40
Ultimate Tensile strength (MPa)	2.87	3
Tensile strain capacity (%)	2.72	0.01

Conclusions and Future Work

- Micromechanical modeling can be successfully applied to geopolymer to develop ultra-ductile fiber reinforced geopolymer composites.
- Fly ash-based fiber reinforced geopolymer shows excellent ductility with tensile strain capacity of 2.72 %.
- Multiple crack propagations and tiny crack width are observed as in ECC materials, which will lead to enhanced durability.
- Future work involves increasing compressive strength to broaden applications. Design of Experiment is a promising design method to develop more appropriate geopolymer matrix with higher strength.
- Life cycle analysis should be conducted to quantitatively evaluate the material greenness of developed composites.

Acknowledgements

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References

[1] V.C. Li , "On Engineered Cementitious Composites (ECC) – A Review of the Material and its Applications," *Advanced Concrete Technology*, Vol. 1, No. 3, pp.215-230, Nov. 2003.

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