UNIVERSITY OF CAMBRIDGE

RESILIENT MATERIALS 4 LIFE

Strain-hardening cementitious composites (SHCC) under cyclic loading conditions for self-healing applications

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BACKGROUND & OBJECTIVES

Concrete structures often suffer from cyclic loads (e.g. earthquakes, traffic, wind) due to the brittle nature of cement matrix. Although traditional reinforcement can help enhance the fracture toughness, macro cracks still generate, threatening the integrity and accelerating the degradation of structures.

Strain-hardening cementitious composites (SHCC), developed based on micromechanical modelling and reinforced with a small volume of short fibres, can achieve a high strain capacity (>3%) through generating multiple fine cracks (width <100 μm). It is a promising material for 1) maintaining structural ductility and load capacity under cyclic loads; 2) enhancing durability; 3) achieving good self-healing effects after damage thanks to the small crack widths.

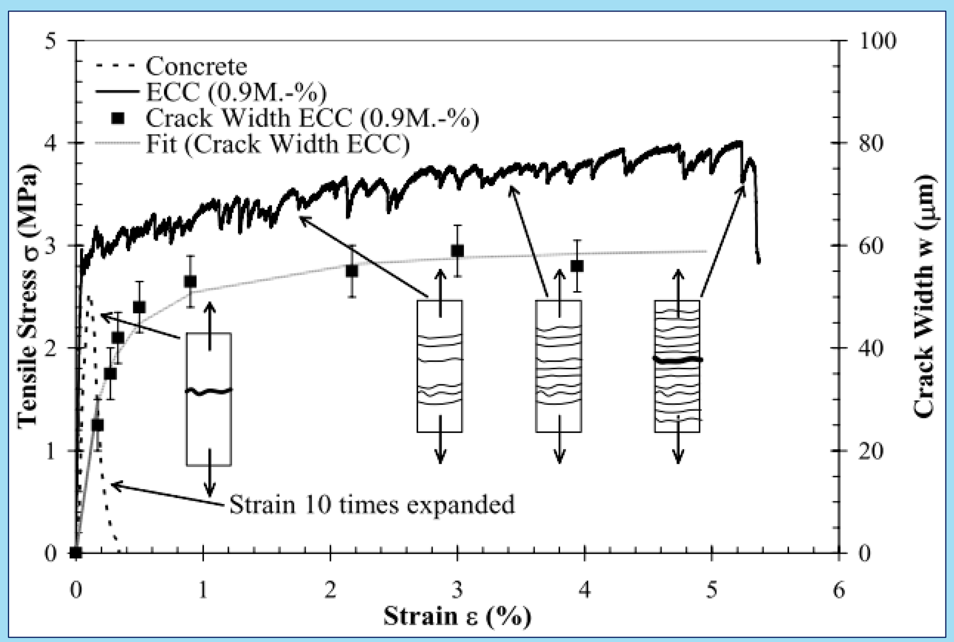

Fig. 1 Tensile stress-strain curve and crack width of SHCC, compared with concrete (Weimann & Li, 2003)

The aim of this research is to develop and optimise self-healing SHCC for cyclic loading conditions.

The present-stage task is to investigate the response of SHCC under various cyclic loading conditions and make comparisons with the monotonic behaviour, thus figuring out different factors affecting the strain capacity and multiple cracking behaviour of SHCC.

MATERIAL COMPOSITION & METHODS

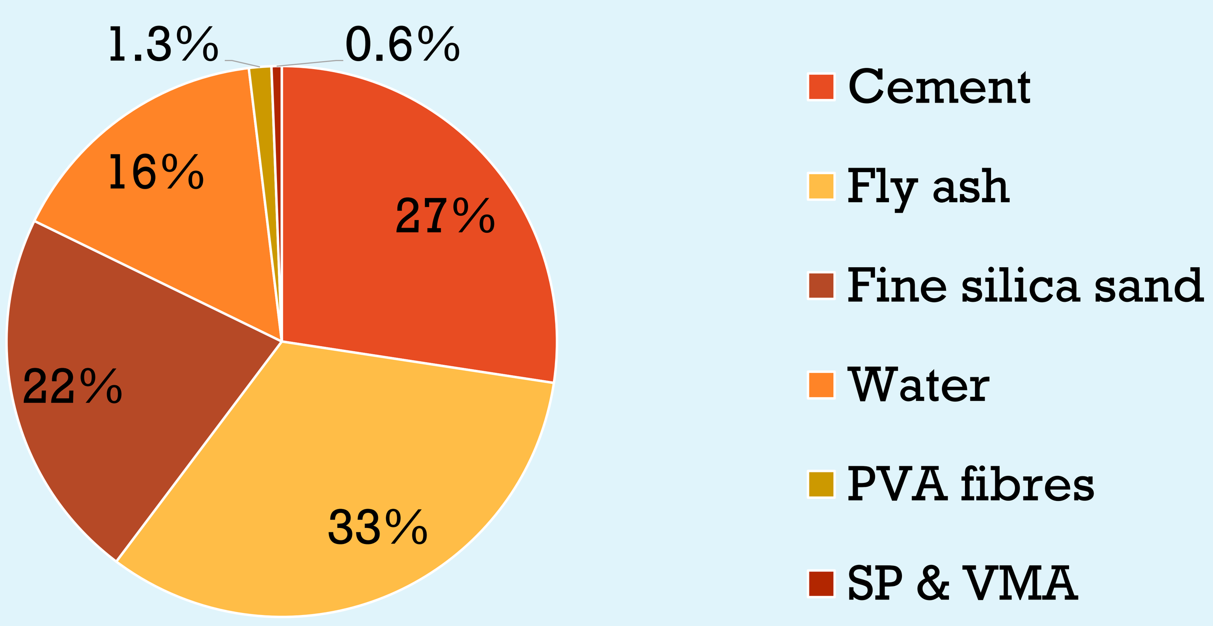

Fig. 2 Mix proportions of SHCC used in this study (M45-ECC, named by Wang & Li (2007))

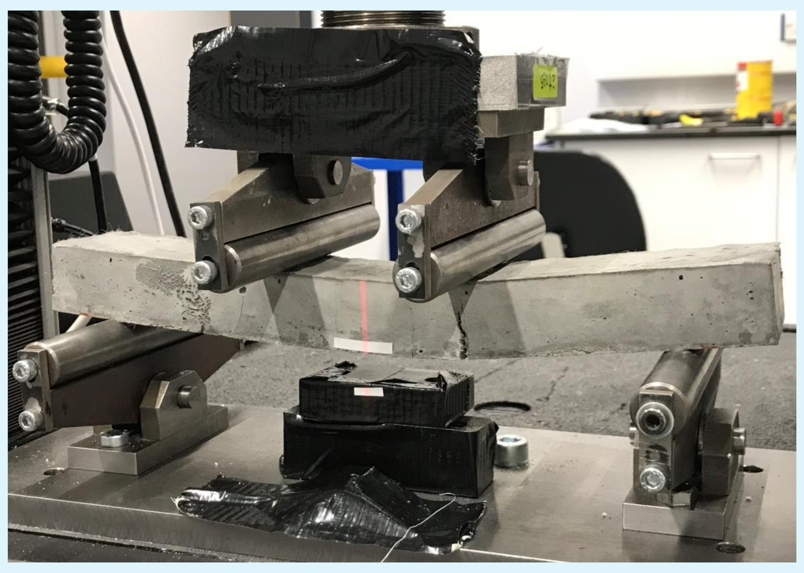

Fig. 3 The setup for four-point flexural tests and large deformation achieved by SHCC

- **Unconfined compressive tests**
- **Four-point flexural tests**
  - **1) Monotonic loading**
  - **2) One-side cyclic**
  - **3) Reversed cyclic**
- **Optical microscopy**

RESULTS

Compressive strength

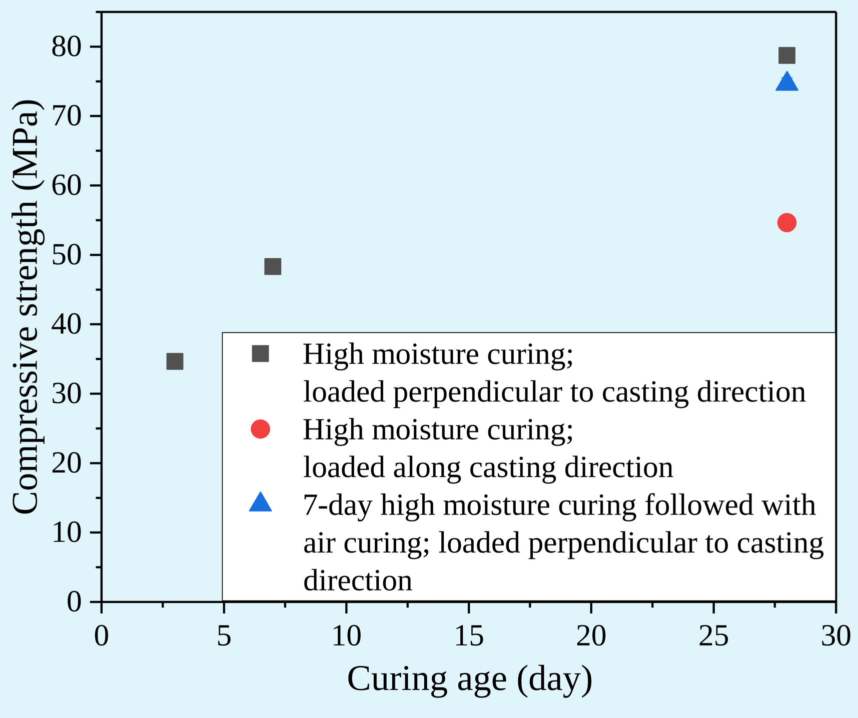

Fig. 4 Development of compressive strength with different curing conditions and loading directions

Flexural stress-deflection

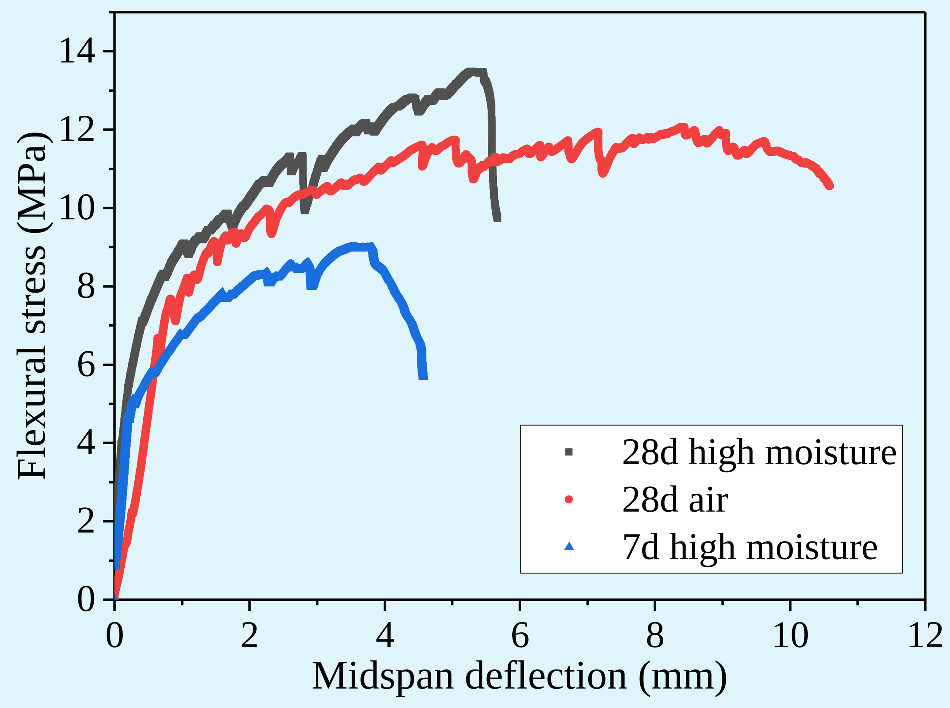

Fig. 5 Flexural stress-midspan deflection curves under different curing conditions and durations

Behaviour under monotonic and cyclic flexural loading

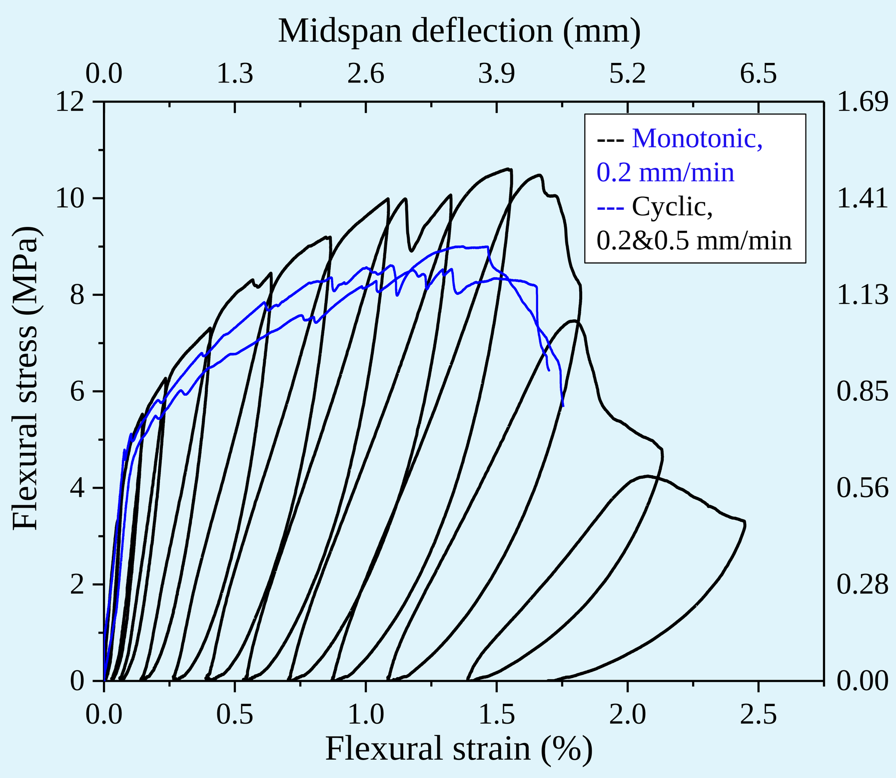

Fig. 6 Behaviour of 7-day SHCC under monotonic and one-side cyclic loading with different quasi-static loading rate

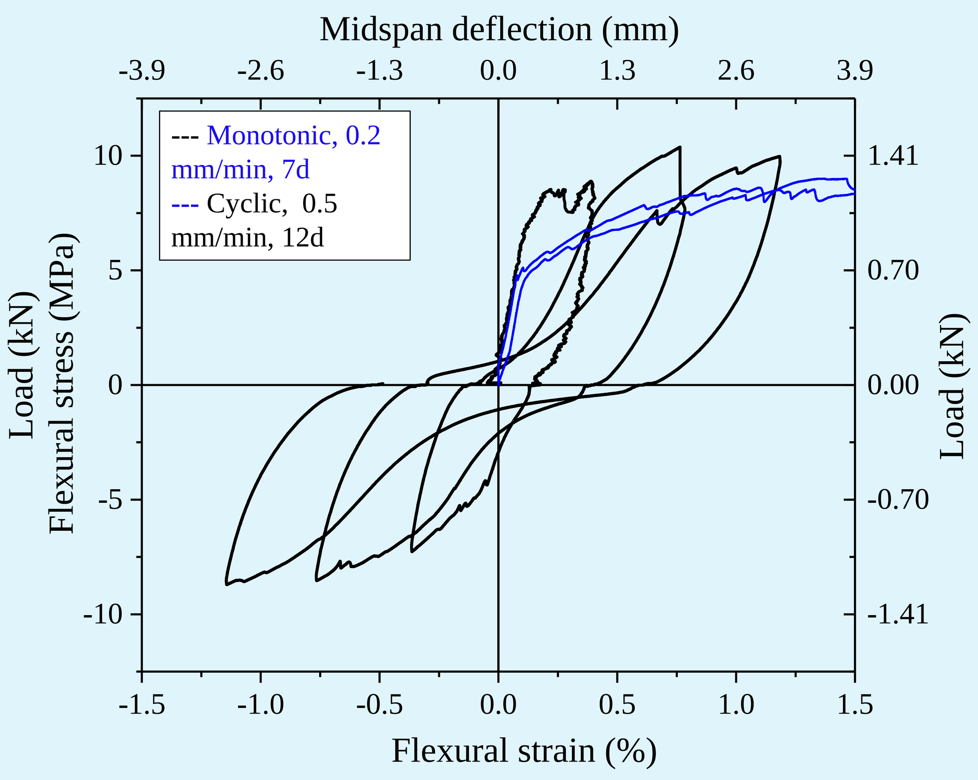

Fig. 7 Behaviour of 7 to 12-day SHCC under reversed cyclic loading compared with monotonic results

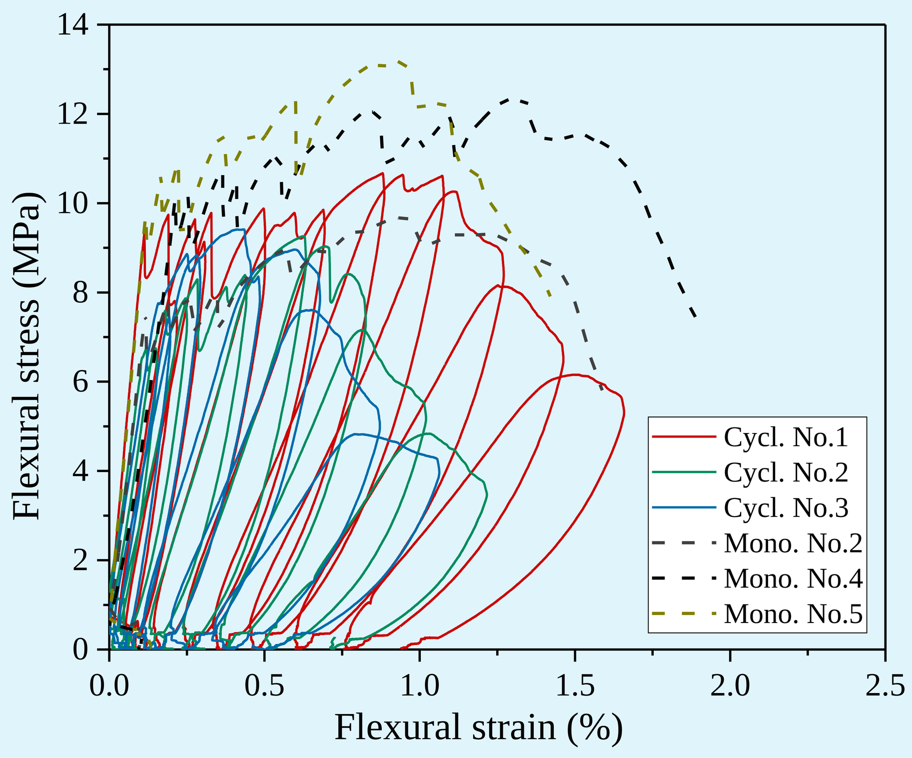

Fig. 8 Behaviour of 28-day SHCC under monotonic and one-side cyclic loading with slow dynamic rate (3 mm/min)

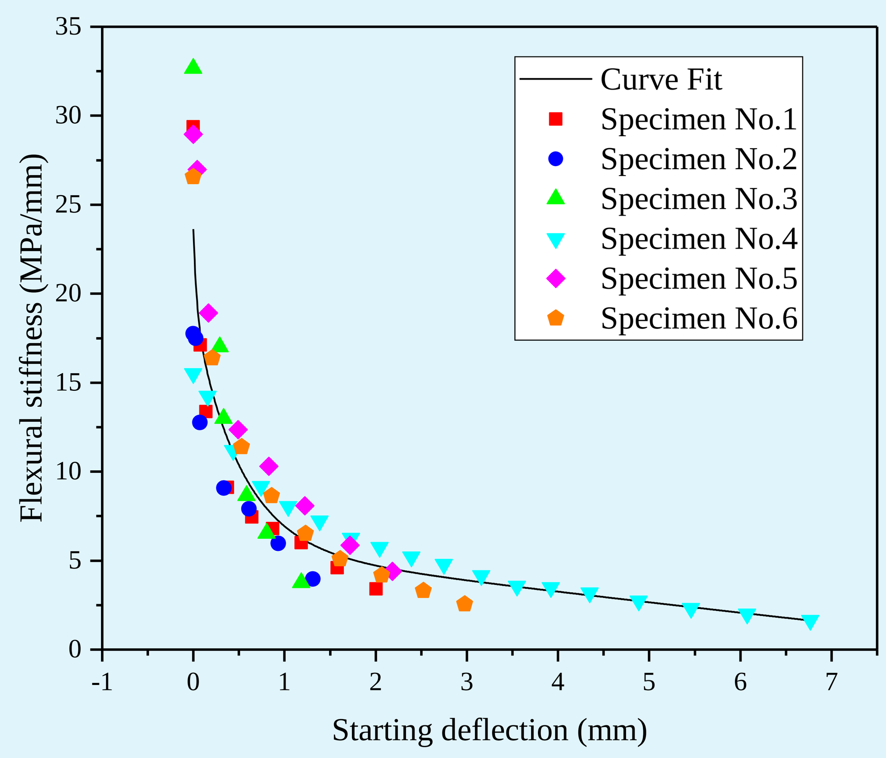

Fig. 9 Reduction of flexural stiffness after each loading cycle

Crack distribution and width measurement

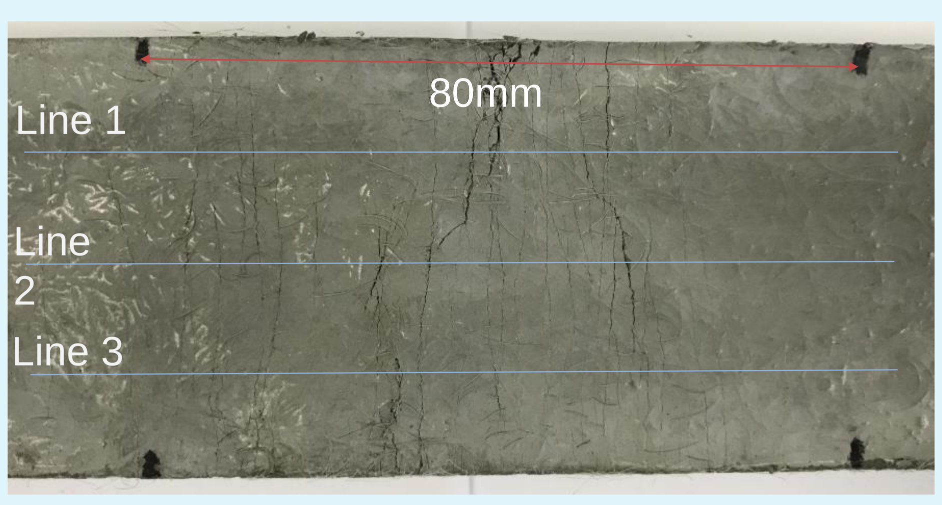

Fig. 10 Surface crack distribution and measuring method

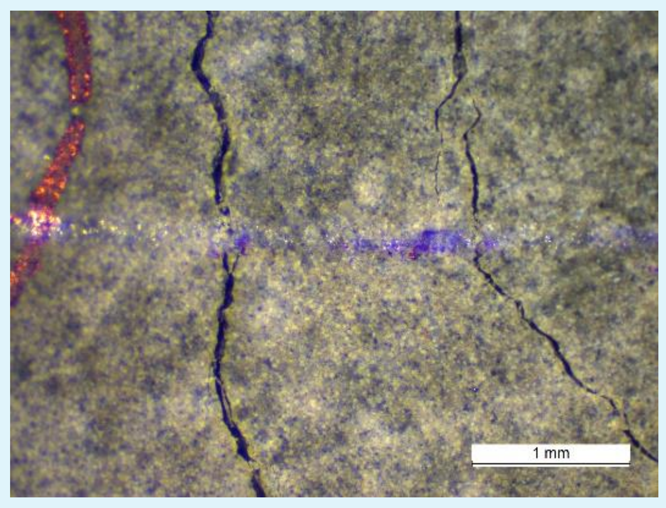

Fig. 11 Crack width below 100 μm under microscope

CONCLUSIONS

Table 1. Effect of different factors on mechanical properties and cracking behaviour of SHCC based on preliminary tests

	Crack number	Crack width	Ductility	Strength
Curing condition/age: 7d vs 28d	<	>	Slightly <	<
Loading type: monotonic vs cyclic	>	Insignificant or slightly <	Insignificant or slightly >	>
Loading direction relative to more fibre alignment: perpendicular vs along	>	<	>	<
Loading rate: quasi-static vs slow dynamic	>	Insignificant	>	<

- Further testing will be conducted to validate the conclusions above.
- Small crack width (<100 μm) and sufficient cementitious materials are desired for efficient self-healing performance, which will be emphasized in future studies.
- Compositions can be tailored based on micromechanical analysis, so as to achieve desired material properties for target applications in different environments, e.g. dynamic and/or cyclic loading conditions.

REFERENCES

- Weimann, M. B., & Li, V. C. (2003). Hygral behavior of engineered cementitious composites (ECC).
- Wang, S., & Li, V. C. (2007). Engineered cementitious composites with high-volume fly ash. ACI Materials journal, 104(3), 233 - 268.

ACKNOWLEDGEMENTS

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